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Für meine Großeltern

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ABSTRACT

This dissertation analyses real exchange rate dynamics and the role of fiscal policy within the setting of a monetary union consisting of two regions. It seeks to address three research questions: What are the policy regimes that yield determinate equilibria in the absence of trade? What is the role of labour mobility across production sectors within an economy in real exchange rate dynamics? And should a national fiscal authority respond to these changes in the real exchange rate, i.e. the domestic inflation differential, to improve domestic welfare?

The first essay finds that with autarkic member countries, a monetary authority following the Taylor principle is insufficient to render an equilibrium determinate if it is not coupled with exactly one 'active' fiscal policy. This is because it can only determine union-wide inflation but not its individual components, i.e. national inflation rates, as it is limited to a single policy instrument, the nominal interest rate. The model shows that fiscal shocks originating in the economy with an active fiscal stance affect domestic inflation but also spill over into the economy whose fiscal policy stance is passive. This finding helps understand to what extent fiscal inflation might materialise in a monetary union in which equalisation of prices is disturbed, as captured by the assumption of autarky in this essay.

The second essay shows that assuming perfect labour mobility across production sectors significantly hampers the model's ability to generate rich real exchange rate dynamics following sector-specific shocks. In an empirical application, I decompose the drivers of Spanish real exchange rate variability and show that estimating the degree of labour mobility considerably improves the model's fit to the data. Moreover, it exposes a distinct transmission mechanism of traded-sector productivity shocks and decisively adjusts the variance decomposition compared to estimation results in a model assuming perfect labour mobility.

The third essay considers real exchange rate variability as a fiscal target for national fiscal authorities in a monetary union. A welfare analysis that calculates consumption equivalents quantifies the benefits of fiscal rules that are responsive to the domestic inflation differential. It finds a large scope for welfare-enhancing fiscal intervention in the set of budget-neutral rules which rely on consumption and labour income taxes. The compression of inflation differentials and thus of domestic inflation raises mean consumption by lowering the degree of price dispersion throughout the economy, thereby outweighing welfare losses that stem from a higher volatility in distortionary taxes.

ZUSAMMENFASSUNG

Diese Dissertation analysiert reale Wechselkursdynamiken und die Rolle von Fiskalpolitik in einer Währungsunion, die sich aus zwei Regionen zusammensetzt. Drei Forschungsfragen werden adressiert: Welche politischen Regime führen in Abwesenheit von Handel zu determinierten Gleichgewichten? Welche Rolle spielt Arbeitsmobilität über Produktionssektoren hinweg innerhalb einer Volkswirtschaft für die Dynamik des realen Wechselkurses? Und sollte nationale Fiskalpolitik auf diese Änderungen des realen Wechselkurses, d.h. auf Inflationsdifferenziale, reagieren, um den inländischen Wohlstand zu erhöhen?

Das erste Essay stellt fest, dass bei autarken Mitgliedsländern eine Geldpolitik nach Taylor-Prinzip nicht ausreicht, um ein Gleichgewicht zu determinieren, wenn sie nicht mit einer "aktiven" Fiskalpolitik gekoppelt ist. Dies liegt daran, dass sie nur die unionsweite Inflationsrate bestimmen kann, nicht jedoch ihre einzelnen Komponenten, d.h. die nationalen Inflationsraten, da sie auf ein einziges politisches Instrument, den nominalen Zinssatz, beschränkt ist. Das Modell zeigt, dass fiskalische Schocks aus der Volkswirtschaft mit einer aktiven Fiskalpolitik die Inlandsinflation beeinflussen, sich aber auch auf die Volkswirtschaft auswirken, deren fiskalische Haltung passiv ist. Dieses Ergebnis hilft zu verstehen, in welchem Maße fiskalische Inflation in einer Währungsunion zustande kommen kann, in der die Preisanpassung gestört ist, wie festgehalten durch die Annahme von Autarkie in diesem Essay.

Das zweite Essay zeigt, dass die Annahme von perfekter Arbeitsmobilität über Produktionssektoren hinweg die Fähigkeit des Modells erheblich beeinträchtigt, ausgiebige Dynamiken des realen Wechselkurses nach sektorspezifischen Schocks zu generieren. In einer empirischen Anwendung zerlege ich die Treiber der spanischen realen Wechselkursvariabilität und zeige, dass die Schätzung der Arbeitsmobilität die Modellanpassung an die Daten erheblich verbessert. Darüber hinaus deckt es einen eindeutigen Übertragungsmechanismus für Produktivitätsschocks im Handelssektor auf und passt die Varianzzerlegung im Vergleich zu Schätzergebnissen in einem Modell an, das perfekte Arbeitsmobilität annimmt.

Der dritte Aufsatz erwägt reale Wechselkursschwankungen als Zielvariable für nationale Fiskalpolitiken in einer Währungsunion. Eine Wohlfahrtsanalyse, die Konsumäquivalente berechnet, quantifiziert die Vorteile von Steuerregeln, die auf das inländische Inflationsdifferenzial reagieren. Sie findet großen Spielraum für wohlfahrtsfördernde, fiskalische Interventionen im Rahmen von budgetneutralen Regeln für Konsum- und Lohnertragssteuern. Die Komprimierung des Inflationsdifferenzials und damit der heimischen Inflation erhöht den Durchschnittskonsum, indem die Preisstreuung in der Volkswirtschaft verringert wird, welches Wohlfahrtsverluste durch volatilere verzerrende Steuern aufwiegt.

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INTRODUCTION

The ratification of the Maastricht Treaty by its last signatory, Germany, irrevocably created the single currency area, the European Monetary Union. The introduction of the euro on 1 January 1999 undoubtedly accelerated the European integration process on an economic and political level, despite the set-backs of the past decade. However, the history of monetary unions and fixed exchange rate regimes reminds us that they are institutions that must be actively maintained and not taken for granted.

The Maastricht Treaty specified several convergence criteria aimed at reducing existing asymmetries and monitoring national fiscal budgets within the envisaged monetary union. The first is directly concerned with inflation. To be eligible to join the monetary union, a country's inflation rate is required to not exceed the average of the three lowest inflation rates observed across EU member states by more than 1.5 percentage points. This alignment of inflation rates was meant to ensure that a centralised monetary authority could use its policy rate to target a union-wide inflation rate composed of relatively similar national inflation rates.

The convergence of inflation rates prior to the introduction of the euro was impressive. In particular, countries in the southern periphery with historically higher inflation rates achieved inflation rates by the late 1990s comparable to those of Germany. However, the return of growing inflation rate dispersion in the 2000s led to a recurring divergence of competitiveness between the European core and periphery countries that could not be addressed by the European Central Bank. A painful readjustment through the real economy seemed inevitable.

The Maastricht criteria concerned with sound and sustainable public finances specified fiscal rules for national governments to follow. Most notably, the government debt-to-GDP ratio should remain below 60% and the annual government budget deficit should not exceed 3% of GDP. After Germany, as the first eurozone country to do so, failed to meet this deficit limit in 2002 and the European Commission abstained from imposing disciplinary measures, the Maastricht criteria lost their bite. With the onset of the global financial crisis, after almost a decade of steady growth, public finances in the southern European periphery eroded visibly and, combined with the loss of external competitiveness, led to the European debt crisis. It became apparent that a better understanding of the role of fiscal policy in currency unions was crucial. The EMU must consider deeper fiscal interaction across borders if it wishes to avoid further economically and politically disrupting crises across its member countries. To this end, this dissertation seeks to contribute to a better understanding of the role of fiscal policy in a currency union, EMU inflation dynamics, and to what extent fiscal policy should actively contribute to a harmonisation of inflation rates.

The first essay, *When the Taylor principle is insufficient – A benchmark for the fiscal theory of the price level in a monetary union*, analyses determinacy regions for policy parameters for two autarkic countries that together constitute a monetary union. The results shed light on equilibrium properties and highlight that, in the absence of an equalisation process of prices through trade integration, union-wide monetary policy conducted according to the Taylor principle will not suffice to uniquely determine individual countries' inflation rates. Furthermore, it is shown how the necessity of an 'active' fiscal policy to uniquely determine an equilibrium leaves scope for fiscal policy spillovers and fiscal inflation.

The second essay, *Real exchange rate dynamics and labour mobility*, deals with the drivers of exchange rate variability in a monetary union from a theoretical as well as an empirical perspective for Spain. Importantly, it analyses the role of labour mobility across production sectors for the transmission mechanism of sector-specific shocks and shows that the assumption of perfect labour mobility significantly impedes the asymmetric transmission mechanism of sector-specific shocks due to identical sector-wages. The estimation results for Spain suggest that labour is imperfectly mobile across sectors. The variance decomposition of real exchange rate variability relative to the rest of the eurozone emphasises demand disturbances as its main driving force, which could imply the necessity of fiscal stabilisation.

Finally, the third essay, *Budget-neutral fiscal rules targeting inflation differentials*, analyses the benefits of budget-neutral tax rules for a national fiscal authority that responds to its domestic inflation differential, i.e. the difference between its domestic inflation rate and the union-wide average. The welfare analysis finds that consumption taxes should be raised while labour income taxes should be lowered in response to domestic inflation exceeding the union-wide average if welfare costs of business cycle fluctuations are to be lowered. By doing so, the fiscal authority compresses the domestic inflation differential by dampening the response of domestic inflation to asymmetric disturbances. In turn, mean price dispersion is lowered, allowing for higher mean consumption under the responsive tax rules. Not only the rules relying on lump-sum financing but also those that exclusively make use of distortionary taxes are able to raise welfare, mostly under both demand as well as supply disturbances. Given the assumption of budget-neutrality, these results help further motivate sustainable fiscal interventions that aim at reducing asymmetries in inflation rates across EMU countries.

FIRST ESSAY

When the Taylor principle is insufficient – A benchmark for the fiscal theory of the price level in a monetary union

This paper derives restrictions on monetary and fiscal policies for determinate equilibria in a two-country monetary union with autarkic members. It finds that a central bank following the Taylor principle may not be sufficient for determinacy unless accompanied by one 'active' fiscal authority as described by Leeper (1991). Alternatively, both fiscal authorities can be active while the central bank abandons the Taylor principle to yield determinacy. The two determinate equilibria have significantly different implications for the transmission of fiscal and monetary shocks and for the fiscal theory of the price level in a monetary union.

1.1 Introduction

There has been a considerable amount of research on the fiscal theory of the price level (FTPL) in the context of monetary unions.[1] However, these analyses seem to be limited, as they rest upon the assumption of a common price level throughout the union. This assumption is generally rationalised by intensified trade within a currency union such that prices and hence inflation rates are perfectly aligned. Yet this appears to be a particularly special case. Often enough, one does not observe the aforementioned alignment of inflation rates but instead persistent and significant differences, for example due to non-tradable goods.

Via the abstraction from trade and thus introduction of country-specific price levels and inflation rates, this paper sheds light on the other end of the spectrum. The results are threefold. First, the analysis shows that the central bank can be impotent to stabilise inflation rates across union countries. Second, it reveals which fiscal policy combinations support determinacy and how spillover effects from national fiscal shocks occur within the union. Third, it uncovers under which conditions fiscal inflation is unavoidable in a monetary union. The results of this paper, based on the assumption of autarkic members of a monetary union, represent an extreme benchmark for the fiscal theory of the price level.

Section 1.2 presents a simple model of a monetary union with one central bank and two fiscal authorities, while Section 1.3 discusses parameter regions which yield determinate, indeterminate, or unstable equilibria. Properties of the determinate equilibria are derived in Section 1.4. Section 1.5 concludes.

1.2 The model

The model is a simple cashless extension of Leeper's (1991) single closed endowment economy of a monetary union consisting of two autarkic countries, Home (H) of size n and Foreign (F) of size $1-n$ with $n \in (0,1)$.[2] While monetary policy is common to both countries in the union, fiscal policies are country-specific. The absence of trade delivers a simple justification for country-specific price levels while preserving the possibility of identical inflation expectations across both countries.

Each country $i \in \{H, F\}$ consists of a single household which maximises expected lifetime utility derived from consumption, C_t, as in

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \log(C^i_{t+k}) \tag{1.1}$$

[1] See for instance Woodford (1996), Sims (1997), Bergin (2000), and Leith & Wren-Lewis (2000).

[2] The results of the single economy in Leeper (1991) are nested in this analysis for $n \in [0;1]$.

subject to

$$C_t^i + \frac{B_t^i}{P_t^i} + \tau_t^i = Y^i + R_{t-1}\frac{B_{t-1}^i}{P_t^i} \quad , \tag{1.2}$$

where R_t denotes the risk-free nominal interest rate set by the central bank, P_t^i the domestic price level, and B_t^i bond holdings of the household of its domestic government. In each period, each country is endowed with $Y^H = Y^F = Y$ units of the consumption good of which a constant fraction $G^H = G^F = G$ is consumed by the respective government.[3]

The households' optimality conditions after imposing market clearing are

$$\frac{1}{R_t} = \beta \mathbb{E}_t\left[\frac{1}{\pi_{t+1}^H}\right] \qquad \text{and} \qquad \frac{1}{R_t} = \beta \mathbb{E}_t\left[\frac{1}{\pi_{t+1}^F}\right] \quad , \tag{1.3}$$

where $\pi_{t+1}^i = P_{t+1}^i / P_t^i$ denotes gross inflation. Evidently, inflation expectations are identical across both member countries of the monetary union. However, actual domestic inflation rates might differ due to country-specific disturbances.

Governments control domestic lump-sum taxes, τ_t^i, and issue debt to finance their expenses, G, in each period. The budget constraint for the government in i reads

$$\frac{B_t^i}{P_t^i} + \tau_t^i = G + R_{t-1}\frac{B_{t-1}^i}{P_t^i} \quad . \tag{1.4}$$

Following Leeper (1991), fiscal authorities adjust their lump-sum taxes in response to the previous period's level of real debt, $b_t^i = B_t^i / P_t^i$, according to

$$\tau_t^i \quad = \quad \gamma_0^i + \gamma^i b_{t-1}^i + \psi_t^i \quad . \tag{1.5}$$

Union-wide inflation, π_t^U, is defined as the weighted average of national inflation rates according to the respective country size such that

$$\pi_t^U = n\pi_t^H + (1-n)\pi_t^F \quad . \tag{1.6}$$

At the union level, the monetary authority sets the nominal interest rate, R_t, in response to union-wide

[3] A positive correlation between the endowment and country size does not alter the results.

inflation as in

$$R_t = \phi_0 + \phi\pi_t^U + \theta_t \quad . \tag{1.7}$$

The country-specific fiscal shocks, ψ_t^i, and the common monetary policy shock, θ_t, are assumed to follow AR(1) processes of the form

$$\psi_t^i = \rho^i\psi_{t-1}^i + e_t^i \quad , \quad \text{where} \quad |\rho^i| < 1, \quad e_t^i \sim \mathcal{N}(0,\sigma_i^2) \quad , \tag{1.8}$$

$$\theta_t = \rho\theta_{t-1} + e_t \quad , \quad \text{where} \quad |\rho| < 1, \quad e_t \sim \mathcal{N}(0,\sigma^2) \quad . \tag{1.9}$$

These innovations represent unsystematic policy behaviour stemming from policy implementation errors or unmodeled economic disturbances. It is assumed that e_t^H, e_t^F and e_t are serially and mutually uncorrelated.

1.3 Model solution and indeterminacy

The model's equations can be reduced to a recursive system in domestic inflation rates and real debt. Combining (1.3) with (1.7) and linearisation yields

$$\mathbb{E}_t\left[\hat{\pi}_{t+1}^H\right] = \phi\beta[n\hat{\pi}_t^H + (1-n)\hat{\pi}_t^F] + \beta\theta_t \quad \text{and} \tag{1.10}$$

$$\mathbb{E}_t\left[\hat{\pi}_{t+1}^F\right] = \phi\beta[n\pi_t^H + (1-n)\pi_t^F] + \beta\theta_t \quad , \tag{1.11}$$

where hat-variables denote deviations from the deterministic steady state.[4] Substitution of the policy rules into the government budget constraints delivers laws of motion for real debt in H and F which read

$$\hat{b}_t^H = (1/\beta - \gamma^H)\hat{b}_{t-1}^H - \frac{b}{\pi\beta}\hat{\pi}_t^H + \frac{b\phi}{R\beta}\hat{\pi}_{t-1}^U - \psi_t^H + \frac{b}{R\beta}\theta_{t-1} \quad \text{and} \tag{1.12}$$

$$\hat{b}_t^F = (1/\beta - \gamma^F)\hat{b}_{t-1}^F - \frac{b}{\pi\beta}\hat{\pi}_t^F + \frac{b\phi}{R\beta}\hat{\pi}_{t-1}^U - \psi_t^F + \frac{b}{R\beta}\theta_{t-1} \quad . \tag{1.13}$$

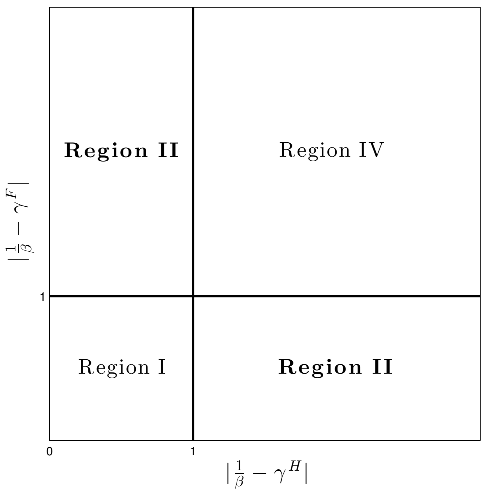
Since $\hat{\pi}_t^U$ can be eliminated, the system consists of two state ($\hat{b}_t^H$, $\hat{b}_t^F$) and two jumping ($\hat{\pi}_t^H$, $\hat{\pi}_t^F$) variables. According to Blanchard & Kahn (1980), the system requires two stable and two unstable roots in order to be determinate.

As in Leeper (1991), a policy is considered to be 'active' ('passive') if the respective authority is unconstrained (constrained) by budgetary conditions such that the associated eigenvalue with this policy is

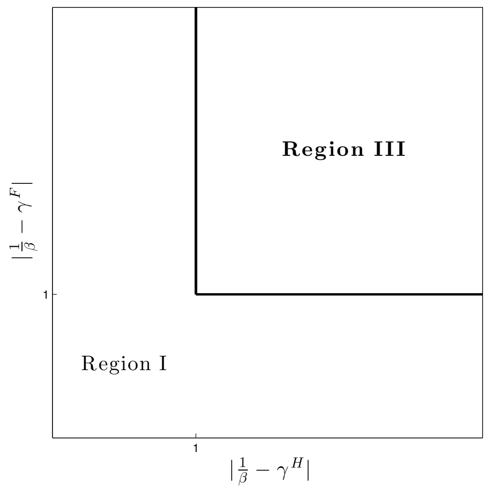
[4] Due to the model's near linearity, linearisation delivers a reasonably accurate approximation.

greater (smaller) than one in absolute values. The two eigenvalues associated with fiscal policy parameters are $\frac{1}{\beta} - \gamma^H$ and $\frac{1}{\beta} - \gamma^F$, and are identical to Leeper's one-country case. The eigenvalue associated with monetary policy is $\phi\beta$, while the last eigenvalue of the system is zero. The zero-eigenvalue is a result that is independent of the size parameter n and implies that monetary policy can only fix one jumping variable.

Figure 1.1 illustrates parameter regions of eigenvalues associated with fiscal policies dependent on the monetary policy regime being active or passive. Region I is characterised by having three to four stable



(a) Active monetary policy ($|\phi\beta| > 1$)



(b) Passive monetary policy ($|\phi\beta| < 1$)

Figure 1.1: Parameter regions

roots such that equilibria in this region are indeterminate. In Figure 1.1a in Region II, the combination of active monetary policy and one active fiscal authority yields exactly enough stable roots for determinacy. Similarly, in Region III in Figure 1.1b, two active fiscal policies in conjunction with passive monetary policy provide two unstable and two stable roots for the system yielding a determinate equilibrium. In Region IV in Figure 1.1b however, three active authorities generate three unstable roots, preventing the existence of a stable equilibrium.

The striking result is that an active monetary policy following the Taylor principle via ϕ, i.e. raising the interest rate by more than one in response to variations in inflation, fails to uniquely determine an equilibrium unless it is accompanied by one active fiscal policy as displayed by Region II in Figure 1.1a. Mathematically, equations (1.6), (1.10) and (1.11) form a subsystem in three variables which does not deliver a unique solution, as has been already indicated by the zero-eigenvalue of the full system. Active monetary policy alone is not able to resolve the inherent indeterminacy.

The economic intuition for this result is straightforward. The central bank has one available policy instrument with which it can uniquely determine union-wide inflation. But due to the isolation of each country within the union, country-specific inflation rates are not uniquely tied together. So even if the weighted average of individual inflation rates, $\hat{\pi}_t^U$, is determined by monetary policy, its components, $\hat{\pi}_t^H$ and $\hat{\pi}_t^F$, may drift apart. Thus, active monetary policy on the union level combined with two passive fiscal policies necessarily renders the equilibrium indeterminate.[5]

1.4 Equilibrium properties

The following section derives certain properties of the two determinate equilibria in order to illustrate differences in shock transmission mechanisms and the possibility of fiscal inflation across equilibria.

1.4.1 Region II equilibrium

When monetary policy is active ($|\phi\beta| > 1$), one can solve for union-wide inflation by combining (1.10) and (1.11) to

$$\hat{\pi}_t^U = \frac{\beta}{\rho - \phi\beta}\theta_t \quad . \tag{1.14}$$

Union-wide inflation is entirely determined by monetary policy shocks, θ_t, while country-specific fiscal shocks have no impact.

When fiscal policy in H is active ($|1/\beta - \gamma^H| > 1$), its respective budget constraint has the forward solution

$$\hat{b}_t^H = \frac{\rho^H}{1/\beta - \gamma^H - \rho^H}\psi_t^H \quad , \tag{1.15}$$

where debt depends solely on domestic fiscal shocks. Substitution back into the budget constraint yields H's inflation rate which reads

$$\hat{\pi}_t^H = -\frac{\pi\beta}{b^H}\left(\frac{1/\beta - \gamma^H}{1/\beta - \gamma^H - \rho^H}\right)\psi_t^H + \frac{\pi\beta}{b^H}(1/\beta - \gamma^H)\hat{b}_{t-1}^H + \phi\beta\hat{\pi}_{t-1}^U + \beta\theta_{t-1} \quad . \tag{1.16}$$

The inflation rate under an active fiscal regime depends on domestic fiscal shocks as well as on past monetary policy shocks. Under active fiscal policy, domestic fiscal shocks cause a wealth effect for

[5] Note that this result is independent of the size parameter $n \in (0, 1)$.

domestic residents, thereby explaining the dependence of $\hat{\pi}_t^H$ on ψ_t^H and revealing the scope for fiscal inflation. In the absence of domestic fiscal shocks, $\hat{\pi}_t^H$ is pegged to expected union-wide inflation, as the last two expressions in Equation (1.16) represent $\mathbb{E}_{t-1}[\hat{\pi}_t^U]$.

Finally, via (1.6) the inflation rate in F is found to read

$$\begin{aligned}\hat{\pi}_t^F &= \frac{1}{1-n}\frac{\beta}{\rho-\phi\beta}\theta_t \\ &+ \frac{n}{1-n}\left[\left(-\frac{\pi\beta}{b^H}\right)\left(\frac{1/\beta-\gamma^H}{1/\beta-\gamma^H-\rho^H}\right)\psi_t^H + \frac{\pi\beta}{b^H}(1/\beta-\gamma^H)\hat{b}_{t-1}^H + \phi\beta\hat{\pi}_{t-1}^U + \beta\theta_{t-1}\right] \quad .\end{aligned} \tag{1.17}$$

Inflation in F responds to fiscal shocks originating in H but not to domestic fiscal shocks. These fiscal shock spillovers are of such magnitude that $\hat{\pi}_t^U$ remains at its steady state due to the active monetary policy. Fiscal shocks in F do not affect $\hat{\pi}_t^F$, as its fiscal stance ensures domestic debt stability, i.e. they do not cause a wealth effect. Hence fiscal inflation is not present in F.

Lastly, the debt stock in F evolves according to the backward solution of its government budget constraint

$$\hat{b}_t^F = \sum_{k=0}^{\infty}(1/\beta-\gamma^F)^k\left(\frac{-b^F}{\pi\beta}\hat{\pi}_{t-k}^F + \frac{b^F}{R\beta}\left(\frac{\rho}{\rho-\phi\beta}\right)\theta_{t-1-k} - \psi_{t-k}^F\right) \quad . \tag{1.18}$$

1.4.2 Region III equilibrium

Under passive monetary policy, both its associated eigenvalues are smaller than one. Consequently, determinacy requires both fiscal policies to be active so that both government budget constraints have a forward solution:

$$\hat{b}_t^H = \frac{\rho^H}{1/\beta-\gamma^H-\rho^H}\psi_t^H \quad \text{and} \tag{1.19}$$

$$\hat{b}_t^F = \frac{\rho^F}{1/\beta-\gamma^F-\rho^F}\psi_t^F \quad . \tag{1.20}$$

Equilibrium real debt depends on the respective fiscal shock of the country but is unaffected by monetary policy shocks. As before, one can substitute $\hat{b}_t^i$ back into the respective government budget constraint to determine individual inflation rates which read

$$\hat{\pi}_t^H = -\frac{\pi\beta}{b^H}\left(\frac{1/\beta-\gamma^H}{1/\beta-\gamma^H-\rho^H}\right)\psi_t^H + \frac{\pi\beta}{b^H}(1/\beta-\gamma^H)\hat{b}_{t-1}^H + \phi\beta\hat{\pi}_{t-1}^U + \beta\theta_{t-1} \quad \text{and} \tag{1.21}$$

$$\hat{\pi}_t^F = -\frac{\pi\beta}{b^F}\left(\frac{1/\beta-\gamma^F}{1/\beta-\gamma^F-\rho^F}\right)\psi_t^F + \frac{\pi\beta}{b^F}(1/\beta-\gamma^F)\hat{b}_{t-1}^F + \phi\beta\hat{\pi}_{t-1}^U + \beta\theta_{t-1} \quad . \tag{1.22}$$

Inflation in i depends on its domestic fiscal shock, meaning that both countries exhibit scope for fiscal inflation. Contrary to the case in Region II, there are no direct spillovers of domestic fiscal shocks to the other country in the union. As before, by behaving actively a fiscal authority pegs its national inflation rate to the expected union-wide inflation.

Finally, by combining (1.21) and (1.22) one obtains the expression for union-wide inflation

$$\begin{aligned}\hat{\pi}_t^U &= n\left[-\frac{\pi\beta}{b^H}\left(\frac{1/\beta-\gamma^H}{1/\beta-\gamma^H-\rho^H}\right)\psi_t^H + \frac{\pi\beta}{b^H}(1/\beta-\gamma^H)\hat{b}_{t-1}^H\right] \\ &+ (1-n)\left[-\frac{\pi\beta}{b^F}\left(\frac{1/\beta-\gamma^F}{1/\beta-\gamma^F-\rho^F}\right)\psi_t^F + \frac{\pi\beta}{b^F}(1/\beta-\gamma^F)\hat{b}_{t-1}^F\right] \\ &+ \phi\beta\hat{\pi}_{t-1}^U + \beta\theta_{t-1} \quad ,\end{aligned} \tag{1.23}$$

which is no longer shielded from country-specific fiscal disturbances. Similarly to the case for a single economy, a passive monetary authority loses the ability to determine its associated inflation rate on its own.

1.5 Conclusion

This paper finds that a central bank may fail to stabilise inflation across autarkic member countries of a monetary union. This result calls into question the universal validity of the Taylor principle when inflation rates of individual member countries are not tied together due to e.g. adjustments in terms of trade. Additionally, these findings have implications for the FTPL in a monetary union, as they show how an active or irresponsibly acting fiscal policy might be necessary for determinacy and how this allows for fiscal inflation.

Because they concern the extreme case of autarky across union member countries, the results serve as a benchmark and motivate a deeper analysis of multiple equilibria and fiscal inflation in multi-country settings with trade in goods and financial assets. Future research should focus on the inclusion of these features and analyse how different policy coordination schemes in a monetary union alter equilibrium characteristics.

SECOND ESSAY

Real exchange rate dynamics and labour mobility

This paper shows that labour mobility across sectors plays a crucial role in determining real exchange rate dynamics following sector-specific shocks. In particular, a New Keynesian DSGE model of a monetary union with perfect intersectoral labour mobility cannot reproduce a real appreciation when traded-sector productivity increases. Allowing for imperfect intersectoral labour mobility enables the model to produce a potential appreciation through rising non-traded goods prices and delivers testable restrictions for model parameters governing the degree of labour mobility. A Bayesian estimation of the model for Spain and the rest of the eurozone finds that allowing for imperfect intersectoral labour mobility significantly improves the model fit to the data and adjusts the relative contribution of shocks to the variability of observables. Posterior impulse response functions show that traded-sector productivity shocks lead to an overall depreciation due to a strong countervailing terms of trade effect despite rising non-traded goods prices.

2.1 Introduction

What are the effects of changes in traded-sector productivity on the real exchange rate? In the presence of non-traded goods, the textbook answer concerned with the long-run is given by Balassa (1964) and Samuelson (1964) through the Balassa-Samuelson effect stating that positive productivity growth differentials drive a real appreciation.[1] Considering the dynamics of the real exchange rate in the short-run, New Keynesian models on the other hand would suggest that at least traded goods prices fall in response to traded-sector productivity shocks. This is because marginal costs decrease with higher productivity so that firms lower their prices, implying a depreciation of the real exchange rate.[2]

In this paper, I analyse the role of labour mobility across production sectors in the context of a two-country New Keynesian model of a monetary union and its implications for the dynamics of the real exchange rate following sector-specific productivity shocks. A prior predictive analysis or model validation exercise in the spirit of Geweke (2007), Faust & Gupta (2012), and Leeper et al. (2017) shows how probability bands of theoretical impulse response functions of the real exchange rate, the terms of trade, and non-traded goods prices are affected by the degree of intersectoral labour market mobility.

I find that under perfect intersectoral labour mobility, traded-sector productivity shocks cannot lead to an appreciation of the real exchange rate because of falling nominal wages and hence marginal costs across both sectors. This is due to the standard feature in New Keynesian models that labour demand and nominal wages fall in response to productivity shocks. Under perfect intersectoral labour mobility and thus equal sector wages, the fall in nominal wages materialises symmetrically across both sectors. In this respect, the model is irreconcilable with a Balassa-Samuelson rationale. When labour is not perfectly mobile across sectors, traded-sector productivity shocks are shown to potentially produce an appreciation of the real exchange rate through rising prices in the non-traded sector. This is because under imperfect intersectoral labour mobility, the fall in nominal wages in the traded sector is not directly transmitted to the non-traded sector, so that real labour income potentially increases, leading to a demand expansion and thus rising prices for non-traded goods.

It is also emphasised that, irrespective of the specification of the labour market, under home bias the terms of trade effect on the real exchange rate is negative. This is because given higher productivity, firms in the traded sector lower their prices as marginal costs decline. The terms of trade necessarily increase

[1] Several papers acknowledge the contribution of Harrod (1933) and refer to the Harrod-Balassa-Samuelson effect. The observation of higher price levels in advanced economies can also be explained via demand instead of supply side factors as prescribed by the Balassa-Samuelson theory. See for instance Bergstrand (1991) who proposes homothetic preferences where non-traded goods are luxuries and traded goods necessities to explain higher price levels in rich countries.

[2] This is a general property of New Keynesian models that is robust to various model extensions.

and hence favour a depreciation of the real exchange rate.[3] Whether traded-sector productivity shocks lead to an appreciation is thus the result of the response of non-traded goods prices and the countervailing effect coming from the terms of trade. Nesting both perfect and imperfect intersectoral labour mobility via a CES specification as in Horvath (2000) delivers testable restrictions for the parameters in a Bayesian estimation of the model. This allows one to disentangle the effect of transitory traded-sector productivity shocks on the real exchange rate.

Given the theoretical findings, the model is taken to the data to explain inflation and thus exchange rate variability of Spain vis-à-vis the rest of the eurozone for the years 1996-2007. The results suggest that labour is not perfectly mobile across sectors and that the model allowing for imperfect intersectoral labour mobility provides a significantly improved fit to the data. Posterior impulse response functions support a rise in non-traded goods prices following traded-sector productivity shocks that is outweighed nonetheless by a strong terms of trade effect, leading to an overall depreciation of the real exchange rate. The variance decomposition for the model allowing for imperfect intersectoral labour mobility assigns less weight to traded-sector productivity shocks in driving inflation rate and exchange rate dynamics and emphasises the role of demand disturbances in driving changes in the real exchange rate. These results refine earlier findings by Rabanal (2009) and add to arguments by López-Salido et al. (2005), who emphasised that demand factors are behind Spanish inflation dynamics.

Originally, the long-run theory sparked by Balassa (1964) and Samuelson (1964) aimed at explaining high inflation rates in catching-up or developing economies. With rising inflation rate dispersion and thus diverging real exchange rate dynamics since the introduction of the euro, as surveyed by De Haan (2010), a vast array of economists has been investigating to what extent the Balassa-Samuelson effect could have played a role within the European Monetary Union. This is because (i) the common currency area delivers fertile ground to identify and test for a Balassa-Samuelson effect as nominal exchange rates are fixed and (ii) at the same time rising inflation rate dispersion in the euro area poses a potential problem for policy makers as monetary policy instruments are limited. If inflation rate differentials are persistent, external competitiveness of the members of the currency union will necessarily diverge, leading to large external imbalances. It has therefore been extensively discussed whether national fiscal authorities should intervene and compress differences in inflation rates.[4]

Empirical support for the Balassa-Samuelson hypothesis as an explanation of European real exchange

[3]This confirms earlier works dealing with the terms of trade in the context of the Balassa-Samuelson effect such as Choudhri & Schembri (2010) and Bordo et al. (2017). See also Corsetti et al. (2007) and Corsetti et al. (2008) for the role of the terms of trade in the international transmission of productivity shocks, however in the absence of non-traded goods.

[4]See for instance Beetsma & Jensen (2005), Kirsanova et al. (2007), Duarte & Wolman (2002), Duarte & Wolman (2008), and the third essay of this dissertation.

rate dynamics has been relatively weak.[5] Most recently though, Berka et al. (2018) show for a panel of nine eurozone countries from 1995-2009 that real exchange rate variations in the euro area have been following the Balassa-Samuelson rationale if one controls for differences in unit labour costs. They perform regressions on simulated data from a DSGE model of a two-country monetary union including shocks to productivity as well as to the labour supply that confirm the empirical findings. Nevertheless, their model does not allow to test for the presence of a Balassa-Samuelson effect via parameter restrictions but can only replicate the empirical findings via the introduced shocks to the labour wedge. This paper contributes to this strand of the literature by delivering testable parameter restrictions that allow to test for the Balassa-Samuelson rationale in real exchange rate dynamics via a Bayesian estimation of the model.

Naturally, productivity shocks and the Balassa-Samuelson rationale should not be considered to be the single source of real exchange rate variability. Besides demand-side effects as emphasised by López-Salido et al. (2005), differences in market structures can, even under union-wide shocks, lead to a heterogeneous transmission and thus inflation differentials. These differences could materialise in product and labour markets, as suggested by Angeloni & Ehrmann (2007), Andrés et al. (2008), Campolmi & Faia (2011), Morsy & Jaumotte (2012), and Abbritti & Mueller (2013), as well as in financial markets, as suggested by Hristov et al. (2014) and Gilchrist et al. (2017). These asymmetries lead to differing inflationary processes that can be captured by different parameter estimates. A Bayesian estimation of a structural two-country DSGE model allows one to evaluate the three main hypotheses – (i) supply side factors (Balassa-Samuelson rationale), (ii) demand side factors, and (iii) market asymmetries – and analyse their relative contribution to exchange rate dynamics in the recent past of the eurozone via variance decompositions.

The paper proceeds as follows: Section 2.2 presents the model setup of the monetary union consisting of two economies featuring two sectors of production. Section 2.3 analyses the model's ability to deliver testable restrictions for the Balassa-Samuelson effect through the conventional and terms of trade channel. Section 2.4 analyses the sources of real exchange variability of Spain vis-à-vis the rest of the eurozone via Bayesian estimation and variance decomposition. Section 2.5 concludes.

[5] A non-exhaustive list of works concerned with the core eurozone includes Ortega (2003), who illustrates that the lion's share of the relative appreciations vis-à-vis Germany were driven by non-traded goods prices while in the southern periphery this was due to non-traded markups and wages, and Honohan & Lane (2003), who focus on Ireland and emphasise the channel of nominal effective exchange rates. Moreover, Rabanal (2009) and López-Salido et al. (2005) focus on Spain, where the latter emphasise the channel of demand biased towards non-traded goods and real wage rigidities. Angeloni & Ehrmann (2007) and Égert (2007) employ panel regressions and conclude that demand and cost-push shocks were the main drivers of inflation differentials across the eurozone. Contrarily, estimation results by Mihaljek & Klau (2008) suggest that the Balassa-Samuelson effect was a significant driving force of inflation differentials of the CEE countries vis-à-vis the eurozone, which explains around a quarter of the observed variability.

2.2 A two-sector, two-country model of a monetary union

The model largely follows the one presented in Rabanal (2009) and describes a monetary union consisting of two countries each populated by a measure one of households that have access to an internationally traded bond. A share $1-n$ lives in the home economy (H), the remainder in the foreign economy (F). Each economy produces traded (T) and non-traded goods (N) of which the latter can only be consumed by domestic households. Both economies feature nominal price rigidities in both sectors, and a centralised monetary authority sets a union-wide nominal interest rate. There is no labour mobility across countries, i.e. no migration.[6] In contrast to Rabanal (2009), I employ a labour market specification that allows for imperfect labour mobility across sectors but nests the setup of perfect labour mobility.

The setup of the home economy is presented in the following paragraphs. If not stated otherwise, the setup of the foreign economy is equivalent. Foreign variables are denoted by an asterisk.

2.2.1 Households

Households maximise their expected lifetime utility,

$$\mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \left[U(C_{t+k}) - V(L_{t+k}) \right] \quad , \tag{2.1}$$

derived from consumption, C_t, minus the disutility derived from supplying labour, L_t, to domestic firms. The discount factor is denoted by $\beta \in (0,1)$. Consumption is composed of tradable, $C_{T,t}$, and non-tradable, $C_{N,t}$, consumption goods via

$$C_t = \left[(1-\delta)^{\frac{1}{\zeta}} C_{T,t}^{\frac{\zeta-1}{\zeta}} + \delta^{\frac{1}{\zeta}} C_{N,t}^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}} \quad , \tag{2.2}$$

where ζ measures the substitutability between T and N goods and δ the steady-state share of N goods in the consumption basket. The domestic consumer price level is given by

$$P_t = \left[(1-\delta) P_{T,t}^{1-\zeta} + \delta P_{N,t}^{1-\zeta} \right]^{\frac{1}{1-\zeta}} \quad , \tag{2.3}$$

where $P_{T,t}$ and $P_{N,t}$ denote the prices of T and N goods respectively. The optimal allocation of consumption expenditures implies that $C_{T,t} = (1-\delta) \left(\frac{P_{T,t}}{P_t} \right)^{-\zeta} C_t$ and $C_{N,t} = \delta \left(\frac{P_{N,t}}{P_t} \right)^{-\zeta} C_t$.

The representative household supplies labour to both sectors earning the real wages $w_{N,t}$ and $w_{T,t}$. I

[6] Labour mobility in Europe has increased but remains a much more muted adjustment channel than in the US, as highlighted by Beyer & Smets (2015).

follow the specification of Horvath (2000) so that hours supplied to the two sectors are aggregated via the CES function,

$$L_t = \left[\alpha^{1-\gamma} L_{T,t}^{\gamma} + (1-\alpha)^{1-\gamma} L_{N,t}^{\gamma}\right]^{\frac{1}{\gamma}} \quad , \tag{2.4}$$

where $0 < \alpha < 1$ is the weight of hours supplied to the traded sector and $1/\gamma$ measures the substitutability or mobility of hours worked across sectors.[7] Barriers to labour mobility could be costs related to sector-specific human capital, relocation or psychological costs due to shifting sectors.

The household maximises lifetime utility given the periodic budget constraint

$$C_t + \frac{B_t}{P_t} = R_{t-1}\frac{B_{t-1}}{P_t} + w_{T,t}L_{T,t} + w_{N,t}L_{N,t} + \Pi_t \quad , \tag{2.5}$$

where B_t denotes the internationally traded bond that yields the gross nominal interest rate, R_t, in $t+1$ and Π_t denotes profit transfers from domestic firms.[8]

The functional forms of utility read

$$U(C_t) = \log(C_t - bC_{t-1}) \quad \text{and} \tag{2.6}$$

$$V(L_t) = \frac{1}{1+\kappa} L_t^{1+\kappa} \tag{2.7}$$

with the degree of internal habit expressed by b and the inverse Frisch elasticity of labour supply by κ. The optimal paths of consumption and hours supplied to the two sectors are described by the set of optimality conditions of the utility maximisation problem. Besides the standard intertemporal Euler equation, one can combine the sectoral labour supply conditions to obtain

$$\frac{w_{T,t}}{w_{N,t}} = \left(\frac{\alpha}{1-\alpha}\right)^{1-\gamma} \left(\frac{L_{T,t}}{L_{N,t}}\right)^{\gamma-1} \quad , \tag{2.8}$$

which summarises the versatility of the Horvath (2000) specification. The model nests the case of perfect labour mobility and equal wages across sectors under $\gamma = 1$ and $\alpha = 0.5$. While calibrations with $\alpha \neq 0.5$ capture constant differences in real wages, the case of imperfect labour mobility when $\gamma > 1$ allows for dynamic differences across sector wages. The prior predictive analysis will show that the specification

[7] An important assumption in the original Balassa-Samuselon theory is that of perfect labour mobility across sectors, implying that relative wages should remain unchanged in repsonse to productivity differentials. Cardi & Restout (2015) show for a panel of fourteen OECD countries that this prediction of the Balassa-Samuelson hypothesis does not hold in the data and suggest employing the Horvath (2000) specification.

[8] The behaviour of the real exchange rate under complete financial markets would be close to identical in this model, as shown in Chari et al. (2002). Thus, the results do not hinge on the assumption of incomplete financial markets.

of the labour market is at the core of determining the model's ability to replicate a Balassa-Samuelson effect.

2.2.2 Firms

Intermediate-goods producers

In each sector there is a continuum of monopolistically competitive firms, indexed by $i \in [0, 1]$, that set their prices in a Calvo fashion with indexation, i.e. a fraction, μ, of firms that are unable to reoptimise prices indexes their price to the previous period's inflation rate. The firms produce intermediate-goods varieties using a linear production technology and sector- and country-specific technology with Z_S, where $S \in \{T, N\}$.

In the non-tradable goods sector, an intermediate-goods firm i produces with

$$Y_{N,t}(i) = \exp(Z_{N,t})L_{N,t}(i) \tag{2.9}$$

and seeks to maximise its expected profit given that with probability θ_N the firm is not able to adjust its price, $P_{N,t}(i)$, in a given period. Formally, it sets its price to solve the problem

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta_N^k Q_{t,t+k} \left[Y_{N,t+k|t}(i) P_{N,t}(i) - W_{t+k}^N L_{N,t+k}(i) \right] \quad , \tag{2.10}$$

where $Q_{t,t+k} = \beta^k \frac{U'(C_{t+k})}{U'(C_t)} \frac{P_t}{P_{t+k}}$ is the stochastic discount factor, $Y_{N,t+k|t}(i)$ the output of firm i in $t + k$ given the price set in t, i.e. $Y_{N,t+k|t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t+k}} \left(\frac{P_{N,t+k-1}}{P_{N,t-1}} \right)^{\mu_N} \right)^{-\epsilon} Y_{N,t+k}$, and W_t^N the nominal wage paid in that sector. μ_N denotes the share of indexing firms.

The setup and maximisation problem of an intermediate-goods producer in the traded sector is analogous. Intermediate goods in the traded sector in the home economy are produced by firm i via the production function

$$Y_{H,t}(i) = \exp(Z_{T,t})L_{T,t}(i) \quad . \tag{2.11}$$

Firm i in the tradable sector sets its price, $P_{H,t}(i)$, to maximise

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta_H^k Q_{t,t+k} \left[Y_{H,t+k|t}(i) P_{H,t}(i) - W_{t+k}^T L_{T,t+k}(i) \right] \quad , \tag{2.12}$$

where with probability θ_H the firm in the traded sector cannot readjust its price and given demand

$Y_{H,t+k|t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t+k}}\left(\frac{P_{H,t+k-1}}{P_{H,t-1}}\right)^{\mu_H}\right)^{-\epsilon} Y_{H,t+k}$. The share of indexing firms is denoted by μ_H.

The sector-technologies are assumed to follow AR(1) processes of the form

$$Z_{N,t} = \rho_{Z_N} Z_{N,t-1} + \epsilon_{Z_N,t} \quad \text{and} \tag{2.13}$$

$$Z_{T,t} = \rho_{Z_T} Z_{T,t-1} + \epsilon_{Z_T,t} + \epsilon_{T,t} \quad . \tag{2.14}$$

Innovations $\epsilon_{Z_S,t}$ are uncorrelated across sectors and countries. $\epsilon_{T,t}$ denotes an area-wide i.i.d. technology innovation in the traded sector.

Retailers

Retailers in both sectors are perfectly competitive and combine intermediate goods to produce the final good to be sold to the household. The final non-traded good, $Y_{N,t}$, is produced with technology $Y_{N,t} = \left(\int_0^1 Y_{N,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}$, where ϵ is the elasticity of substitution across different varieties, $Y_{N,t}(i)$, of the non-tradable intermediate good. Given the technology, retailers in the non-traded sector maximise their profit

$$\max P_{N,t} Y_{N,t} - \int_0^1 P_{N,t}(i) Y_{N,t}(i) di \tag{2.15}$$

which yields the demand function

$$Y_{N,t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t}}\right)^{-\epsilon} Y_{N,t} \quad , \tag{2.16}$$

where $P_{N,t}(i)$ is the price for variety i of the non-traded good and $P_{N,t} = \left(\int_0^1 P_{N,t}(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$.

In the traded sector, retailers combine intermediate home- and foreign-produced traded goods, $Y_{H,t}(i)$ and $Y_{F,t}(i)$, to produce the final traded good, $Y_{T,t}$, consumed by domestic households. They choose their inputs to maximise

$$\max P_{T,t} Y_{T,t} - \int_0^1 P_{H,t}(i) Y_{H,t}(i) di - \int_0^1 P_{F,t}(i) Y_{F,t}(i) di \tag{2.17}$$

subject to technologies

$$
\begin{aligned}
Y_{T,t} &= \left[(1-\omega)^{\frac{1}{\varphi}} Y_{H,t}^{\frac{\varphi-1}{\varphi}} + \omega^{\frac{1}{\varphi}} Y_{F,t}^{\frac{\varphi-1}{\varphi}}\right]^{\frac{\varphi}{\varphi-1}} \quad , & (2.18)\\
Y_{H,t} &= \left(\int_0^1 Y_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \quad \text{, and} & (2.19)\\
Y_{F,t} &= \left(\int_0^1 Y_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \quad , & (2.20)
\end{aligned}
$$

where φ is the elasticity of substitution between final home and foreign traded goods in the production of $Y_{T,t}$ and ω stands for the steady-state share of imported goods in the final traded good. Home bias for home-produced traded goods is present when $\omega < 0.5$.[9] Profit maximisation yields the demand functions

$$
\begin{aligned}
Y^d_{H,t}(i) &= (1-\omega)\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon}\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\varphi} Y_{T,t} \quad \text{and} & (2.21)\\
Y^d_{F,t}(i) &= \omega\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon}\left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\varphi} Y_{T,t} \quad , & (2.22)
\end{aligned}
$$

where $P_{H,t}(i)$ and $P_{F,t}(i)$ are the prices of the home and foreign traded variety i and where the price indices are defined as $P_{H,t} = \left(\int_0^1 P_{H,t}(i)^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$, $P_{F,t} = \left(\int_0^1 P_{F,t}(i)^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$, and $P_{T,t} = \left[(1-\omega)P_{H,t}^{1-\varphi} + \omega P_{F,t}^{1-\varphi}\right]^{\frac{1}{1-\varphi}}$.

Terms of trade and the real exchange rate

Due to the presence of the non-traded goods sector, the model includes external and internal terms of trade. The (external) terms of trade, T_t, are defined as the price of foreign-produced traded goods relative to home-produced traded goods, i.e.

$$
T_t = \frac{P_{F,t}}{P_{H,t}} \quad . \tag{2.23}
$$

A rise in the terms of trade ameliorates the external competitiveness of the home economy as the foreign-produced traded goods become relatively more expensive.

The internal terms of trade, $T_{N,t}$, are defined as

$$
\begin{aligned}
T_{N,t} &= \frac{P_{N,t}}{P_{T,t}} \quad \text{and} & (2.24)\\
T^*_{N,t} &= \frac{P^*_{N,t}}{P^*_{T,t}} & (2.25)
\end{aligned}
$$

[9]Analogously, foreign bias is implied by setting $\omega > 0.5$.

and measure the internal competitiveness across sectors within a country. They capture the price of the non-traded good relative to the final traded good within a member country of the monetary union.

The real exchange rate, rer, is defined as

$$rer = \frac{P_t}{P_t^*} = \frac{P_{T,t}}{P_{T,t}^*}\left(\frac{1-\delta+\delta T_{N,t}^{1-\zeta}}{1-\delta+\delta T_{N,t}^{*1-\zeta}}\right)^{\frac{1}{1-\zeta}} = \left(\frac{(1-\omega)T_t^{\varphi-1}+\omega}{(1-\omega)+\omega T_t^{\varphi-1}}\right)^{\frac{1}{1-\varphi}}\left(\frac{1-\delta+\delta T_{N,t}^{1-\zeta}}{1-\delta+\delta T_{N,t}^{*1-\zeta}}\right)^{\frac{1}{1-\zeta}} \quad , \tag{2.26}$$

which is a function of external and domestic and foreign internal terms of trade. Given the definition, an appreciation (depreciation) of the real exchange rate is shown by an increase (fall) in rer, i.e. the home economy's price level, P, increases (falls) relative to the foreign economy's price level, P^*.

In the textbook Balassa-Samuelson effect, traded goods prices would be identical ($P_{T,t} = P_{T,t}^*$) so that changes in the real exchange rate are entirely driven by differences in non-traded goods prices. A rise in non-traded goods prices leads to an appreciation (or rise) of the real exchange rate via the rise in T_N, i.e. the domestic price level, P, rises relative to the foreign, P^*. By allowing for different traded goods prices via home or foreign bias, the model is able to capture changes in the real exchange rate through changes in the terms of trade. In the absence of non-traded goods ($\delta = 0$), changes in the real exchange rate are entirely driven by the terms of trade.

2.2.3 Monetary policy

Monetary policy is conducted at the union level and responds to average union-wide consumer price inflation $\pi_t^U = (\pi_t)^{1-n}(\pi_t^*)^n$. The Taylor-type interest rate rule reads

$$R_t = \left(\frac{1}{\beta}\right)^{1-\rho_R}(R_{t-1})^{\rho_R}\left(\pi_t^U\right)^{(1-\rho_R)\phi}\exp(\epsilon_{M,t}) \quad , \tag{2.27}$$

where ρ_R denotes the interest rate persistence and ϕ the aggressiveness with which the central bank reacts to union-wide consumer price inflation. $\epsilon_{R,t}$ denotes i.i.d. monetary policy disturbances.

2.2.4 Market clearing

The market clearing conditions for traded and non-traded goods, the labour market, and the international bond market are

$$Y_{T,t} = C_{T,t} + G_{T,t} \quad , \tag{2.28}$$

$$Y_{N,t} = C_{N,t} + G_{N,t} \quad \text{and} \tag{2.29}$$

$$(1-n)\frac{B_t}{P_t} = n\frac{B_t^*}{P_t^*} \quad , \tag{2.30}$$

where G_T and G_N are sector-specific demand disturbances following AR(1) processes that read

$$G_{T,t} = \rho_{G_T} G_{T,t-1} + \epsilon_{G_T,t} \quad \text{and} \tag{2.31}$$

$$G_{N,t} = \rho_{G_N} G_{N,t-1} + \epsilon_{G_N,t} \quad . \tag{2.32}$$

Innovations $\epsilon_{G_T,t}$ and $\epsilon_{G_N,t}$ are i.i.d. and uncorrelated across sectors. A debt-elastic interest rate à la Schmitt-Grohé & Uribe (2003) induces debt-stationarity.

2.3 Prior analysis: The role of intersectoral labour mobility

I perform a prior predictive analysis in order to determine the role of intersectoral labour mobility for real exchange rate dynamics after shocks to traded-sector productivity.[10] I do so by simulating the model and computing prior impulse response functions for the real exchange rate, the external terms of trade, and non-traded goods prices given relatively agnostic priors for parameters that would be included in a Bayesian estimation. I compare probability bands of impulse response functions for the perfect labour mobility model (PLM) with those of the model nesting perfect labour mobility (NPLM) via the Horvath (2000) specification.

2.3.1 Approach

I compute the range of prior impulse response functions, i.e. impulse response functions that the model can produce given calibration and prior range of parameters of interest. I compare two model versions: the perfect labour mobility model (PLM), which calibrates α and γ to 0.5 and 1 respectively, and the

[10]This approach is inspired by Leeper et al. (2017), who show how the size of estimated fiscal multipliers is heavily model-dependant. They find that only by including government consumption in the household's utility function and by varying the parameter governing the degree of substitutability or complementarity of public to private consumption is the model able to produce a respectable range of fiscal multipliers.

nesting perfect labour mobility model (NPLM), in which α and γ can take a range of values to allow for imperfect labour mobility. I proceed in three steps:

1. Given the model structure, $M \in \{PLM, NPLM\}$, I specify prior density functions, $p(\theta_M)$, for the model parameters θ_M. Parameters that are weakly identified or have clear empirical counterparts are assigned point priors, i.e. they are calibrated.

2. Together with the parameter priors, the linearly approximated model delivers ex ante distributions for the model's observables, y_t, from $p(y_t) = \int p(\theta_M)p(y_t|\theta_M)d\theta_M$.

3. The prior predictive analysis draws from $\theta_M \sim p(\theta_M)$ and $y_t \sim p(y_t|\theta_M)$ and computes impulse response functions for y_t given prior draws.

This approach allows to investigate to what extent the transmission of sector-specific productivity shocks to the real exchange rate is affected by the degree of labour mobility. In general, it should be expected that probability bands around prior impulse response functions in the NPLM model should be broader, as it nests the model responses produced in the PLM model.

2.3.2 Calibration and priors

The baseline calibration is for two symmetric countries of equal size. The calibration is summarised in Table 2.1 and mainly follows Duarte & Wolman (2008). Because the steady-state share of non-traded

Description	Parameter	Value
Size of the home economy	$1-n$	0.5
Discount factor	β	0.99
Inverse Frisch elasticity	κ	1
Steady-state share of N goods	δ	0.4
Steady-state import share in T good	ω	0.4
Elasticity of substitution between T and N goods	ζ	0.74
Elasticity of substitution between H and F goods	φ	1.5
Elasticity of substitution across goods varieties	ϵ	10
Weight on L_T in CES	α	0.5
Inverse elasticity of substitution between T and N hours	γ	1

Note: α and γ are only calibrated for the perfect labour mobility (PLM) model.

Table 2.1: Calibrated parameters

goods as well as the steady-state import share would be calibrated in an explicit application to a certain country, they are fixed in the prior predictive analysis. Depending on goods classification schemes, the share of non-tradable goods ranges from approximately 40% to 60% across European economies.[11] Calibrating δ to 0.4 hence represents the lower bound for changes in the real exchange rate caused by changes in the internal terms of trade. A steady-state import share of 0.4 implies a small degree of home bias, allowing for price differentials due to differences in traded goods prices. Again, this calibration should be seen as a lower bound to allow changes in the real exchange rate to be driven by the (external) terms of trade. Importantly, the baseline calibration fixes the parameters α and γ to 0.5 and 1 respectively, corresponding to equal sector wages and perfect labour mobility in the PLM model.

The priors follow standard ranges and distributions from the existing literature, in particular the study by Rabanal (2009), and are displayed in Table 2.2. As changes in the real exchange rate for two countries in a monetary union are reflected by price changes and hence differing inflation rates, parameters linked to price setting by firms are of major interest, i.e. Calvo parameters and the shares of indexing firms. Additionally, the responsiveness and persistence of the nominal interest rate exert significant influence on

Description	Parameter	Distribution	Mean	Std. Dev.
Calvo parameter	$\theta_N, \theta_{N^*}, \theta_H, \theta_F$	Beta	0.75	0.15
Indexation	$\mu_N, \mu_{N^*}, \mu_H, \mu_F$	Beta	0.6	0.2
Habit persistence	b	Normal	0.5	0.1
Monetary policy strength	ϕ	Normal	1.5	0.1
Interest rate rule persistence	ρ_R	Beta	0.7	0.1
Weight on L_T in CES	α	Normal	0.5	0.1
Inverse elasticity of subst. between T and N hours	γ	Uniform	5.5	$9/\sqrt{12}$

Note: α and γ are calibrated to 0.5 and 1 respectively in the perfect labour mobility (PLM) model.

Table 2.2: Priors

inflation dynamics and are thus given some range. In the NPLM model, I allow for imperfect intersectoral labour mobility by setting a uniform prior for the inverse elasticity of substitution between hours supplied to the two sectors, γ, ranging from 1 (perfect labour mobility) to 10 (considerable degree of intersectoral immobility). The prior for the weight of L_T in the CES aggregator, α, is set to a normal distribution with mean 0.5 and standard deviation 0.1.

2.3.3 Results

For the analysis, I generate 100,000 draws from the prior distributions and compute impulse response functions at each draw for the two different model versions, perfect labour mobility (PLM) and nesting

[11] See also Stockman & Tesar (1995) who show that for OECD countries non-traded goods account for around 50% of total consumption.

perfect labour mobility (NPLM). The following graphs display the mean response and 90% probability bands for the computed prior impulse response functions given the priors reported in Table 2.2. The analysis focuses on the response of the real exchange rate, the external terms of trade, and non-traded goods price levels to a one standard deviation increase in traded-sector technology.[12]

To begin with, Figure 2.1 displays the mean impulse response function and 90% probability bands for the external terms of trade and the non-traded goods price level for the PLM model and the NPLM model. Both models yield an increase in external competitiveness, T, following the traded-sector technology

(a) PLM model (b) NPLM model

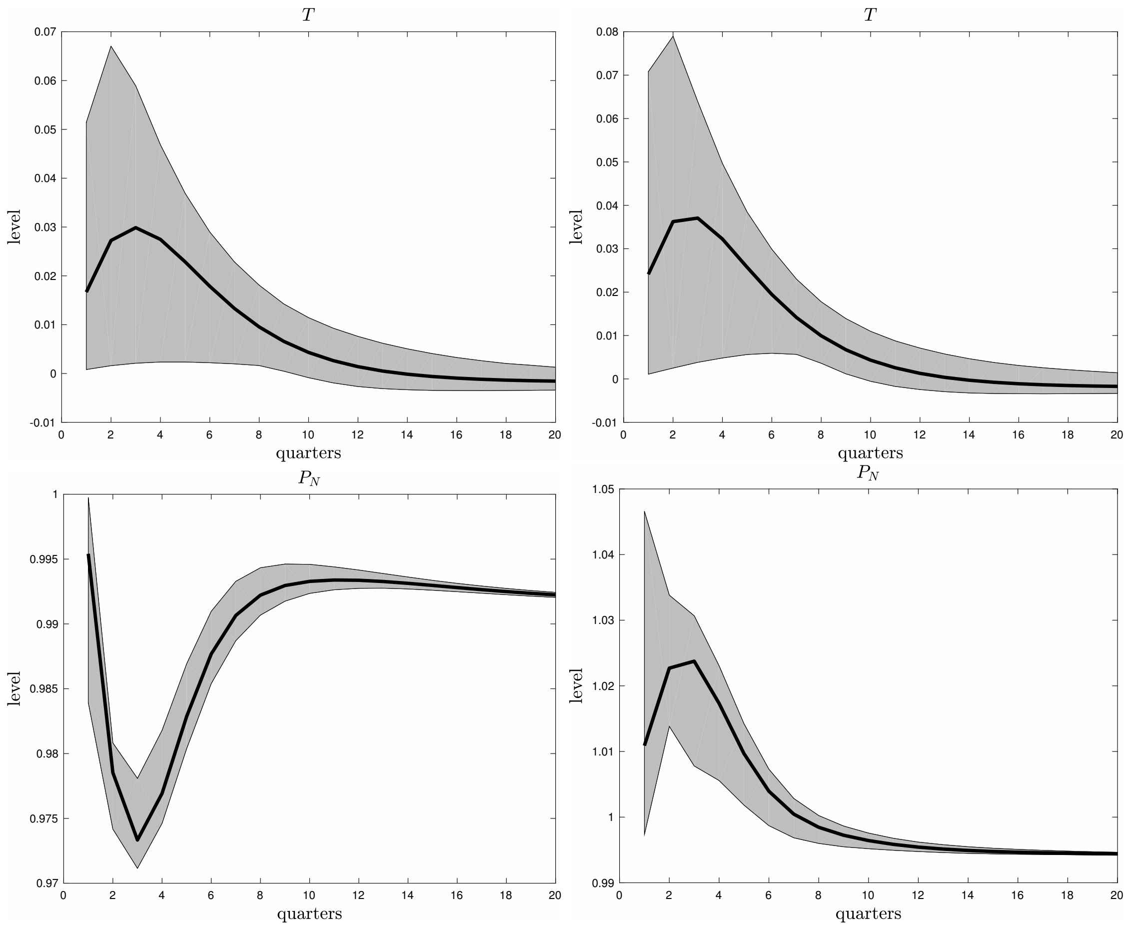


Figure 2.1: Prior mean impulse response functions and 90% probability bands for external terms of trade, T, and non-traded goods prices, P_N, in the perfect labour mobility (PLM) and nesting perfect labour mobility (NPLM) model

shock which supports a depreciation of the real exchange rate. In New Keynesian models, firms set

[12]Note that for this exercise, I calibrate the traded-sector technology shock persistence, ρ_{Z_T}, to 0.7 to focus on the transmission mechanism of the model.

prices with a markup over marginal costs. As marginal costs in the traded sector decrease, firms seek to lower their prices. Irrespective of the degree of intersectoral labour mobility, domestic firms producing traded goods will lower their prices, P_H, so that the external terms of trade will unambiguously increase, favouring a depreciation of the real exchange rate under home bias.

Inspecting price level responses of non-traded goods shows an unambiguous fall of non-traded goods prices in the PLM model. This is because of the common wage structure under perfect intersectoral labour mobility. In a New Keynesian model, an increase in technology leads undoubtedly to a fall in the labour demand of firms.[13] In the specific example of a traded-sector technology shock, firms in the traded sector reduce their labour demand, which leads to a fall in the nominal wage paid in that sector. Under perfect labour mobility and equal sector wages, firms in the non-traded sector also pay lower wages, reducing their marginal costs and allowing them to lower their prices. When labour is not perfectly mobile, the link between sector wages is broken and sector-specific shocks can trigger asymmetric responses within the economy, as non-traded goods prices can rise with higher traded-sector productivity, as shown by the probability bands of impulse response functions of the non-traded goods price level in the NPLM model.

Finally, Figure 2.2 shows that the potential rise in non-traded goods prices in the NPLM model can outweigh the terms of trade effect and produce an appreciation of the real exchange rate. In the PLM

(a) PLM model (b) NPLM model

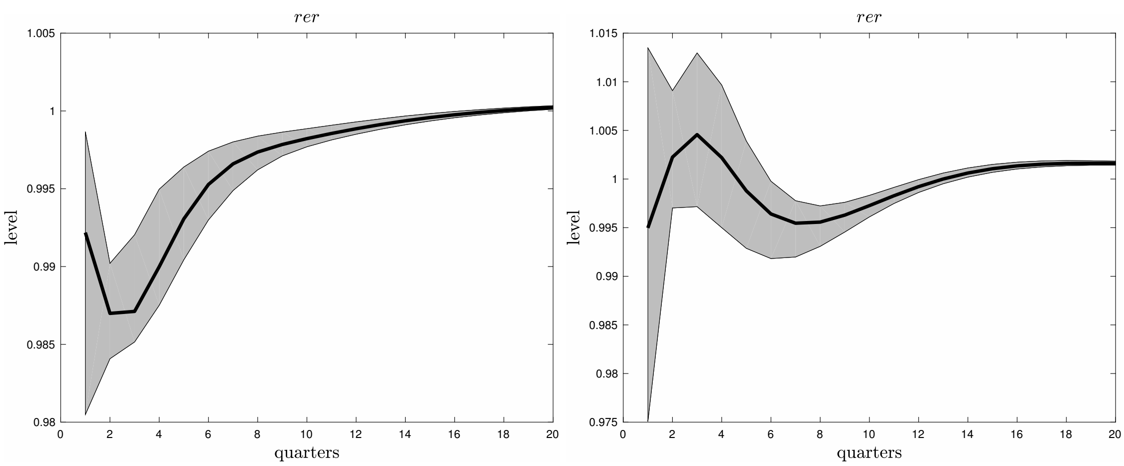


Figure 2.2: Prior mean impulse response functions and 90% probability bands for the real exchange rate, *rer*, in the perfect labour mobility (PLM) and nesting perfect labour mobility (NPLM) model

model, the change in the real exchange rate is undoubtedly negative as a result of i) the terms of trade effect and ii) the transmitted fall in non-traded goods prices through perfect intersectoral labour mobility. The NPLM model, on the other hand, delivers a more agnostic image. While the mean impulse response

[13]This result is robust to the inclusion of capital as well as to the size of the home economy within the union.

function shows a fall in the real exchange rate on impact, the probability bands reveal the greater flexibility of the model relative to a setting with perfect labour mobility. Most importantly, the level of the real exchange rate can rise as well as fall in response to the traded-sector technology shock at various time horizons.

This analysis shows that the degree of labour mobility across sectors is decisive for real exchange rate dynamics following sector-specific shocks. In particular, the assumption of perfect intersectoral labour mobility prevents a two-sector model of a two-country monetary union from replicating higher prices in the non-traded sector due to higher productivity in the traded sector, irrespective of the information contained in the data. The specification of $V(L_{T,t}, L_{N,t})$ and the estimation of the nesting parameters, α and γ, that determine the degree of labour mobility across sectors deliver testable restrictions in the context of a Bayesian estimation.[14] As a result, the model allows to test for a Balassa-Samuelson rationale in the short-run, i.e. rising prices in the non-traded sector due to a positive productivity shock in the traded sector.[15]

2.4 Application: Inflation variability in Spain

After a period of great price level convergence in the late '90s, inflation rate dispersion within the eurozone increased significantly with the introduction of the euro, as surveyed by De Haan (2010).[16] One particularly interesting case is that of Spain. From the late '90s up until the global financial crisis (GFC), Spanish consumer price inflation exceeded the euro area average by a persistently large amount as displayed in Figure 2.3.

It is evident that inflation rates in the services component of the Harmonised Index of Consumer Prices (HICP), serving as a proxy for non-traded goods, had a significant impact on aggregate inflation dynamics. With very few exceptions, inflation differentials in the services component have been at least as high as aggregate differentials, indicating that a large amount of the relative appreciation of Spain has been driven by trends in the non-traded sector. In terms of dynamics on the other hand, the series exhibits a positive correlation of 0.35. This does not, however, allow one to draw concrete conclusions regarding how price dynamics in the non-traded sector affected the real exchange rate over the considered time horizon.

In this section and in line with the previous prior analysis, I want to focus on the drivers of exchange

[14] The identification analysis following Ratto & Iskrev (2011) supports the identification of both α and γ.

[15] In contrast, Berka et al. (2018) relied on the inclusion of shocks to the labour wedge to reconcile a New Keynesian DSGE model with a Balassa-Samuelson effect.

[16] See Rogers (2007), who argues that price levels within the EMU did already converge prior to the introduction of the euro to a comparable level, as can be observed across the states of the U.S.A.

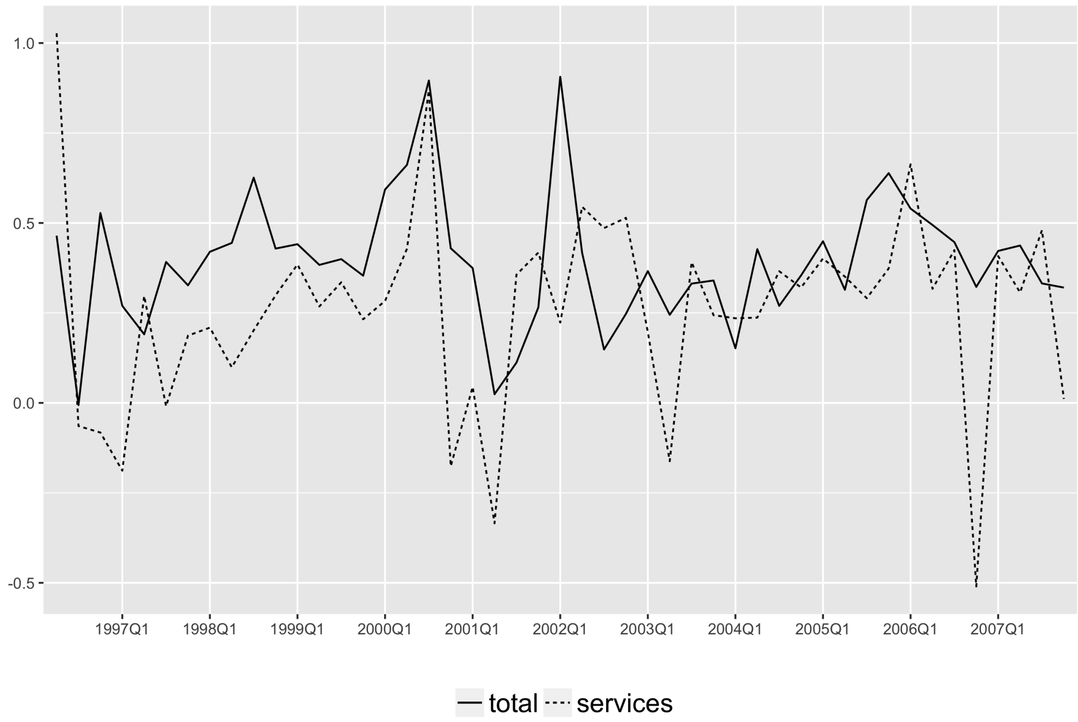


Figure 2.3: Quarterly HICP inflation differentials of Spain vis-à-vis the EA18 (excluding Spain), 1996Q2-2007Q4. Source: Eurostat.

rate variability instead of long-run trends, i.e. I disregard differences in mean inflation rates between Spain and the rest of the eurozone. I do so because the particularly persistent differences in inflation rates between Spain and those of the rest of the eurozone cannot be explained by temporary shocks, but are most likely related to differences in steady-state growth rates of productivity and the like. I seek to compare my estimation results to those of Rabanal (2009), who estimated the perfect labour mobility model and allowed for deterministic growth rates in productivity to capture the mean differences.

For the variability of inflation rates, the estimation allows the nesting of three potential drivers: i) supply side factors (Balassa-Samuelson rationale), ii) demand factors, and iii) heterogeneity in markets captured by different inflationary processes. By estimating the nesting perfect labour mobility model and comparing it to the results of the perfect labour mobility model, I am able to assess the relative importance of imperfect intersectoral labour mobility to disentangle these drivers of inflation variability of Spain. Moreover, it allows me to re-evaluate whether traded-sector productivity shocks in Spain could have had a positive effect on non-traded goods prices, as would be predicted by the Balassa-Samuelson rationale yet was rejected by Rabanal (2009).[17]

2.4.1 Data and priors

I use the same data and priors as Rabanal (2009) for the same time period of 1996Q2 to 2007Q4.[18] I estimate the perfect labour mobility (PLM) and the nesting perfect labour mobility (NPLM) models presented in Section 2.2. I do so using standard Bayesian techniques as discussed by Smets & Wouters (2003) and An & Schorfheide (2007) to evaluate the likelihood function and simulate the posterior distributions of the model parameters. I use 400,000 draws and let the first 120,000 draws be burn-in.

The data is available on Eurostat and includes quarterly data on aggregate and services HICP inflation and real GDP growth rates for Spain and the rest of the EMU. The rest of the EMU comprises the euro area 18 (EA18) excluding Spain. As the monetary policy rate, I use the 3-month T-bill rate of the euro area. As my focus is on the dynamics of the real exchange rate rather than constant differences due to potentially different long-run trends in productivity and the like, the data is demeaned to match the zero mean growth rates of the linearised model.

Parameters are calibrated as shown in Table 2.1 with two exceptions. The size of the home economy, Spain, is set to 0.11, representing the average weight of Spain in the HICP of the EMU, and habit persistence is fixed to 0.5.[19] The prior distributions mirror those of Rabanal (2009) with the exception that for the NPLM model the priors for α and γ from Table 2.2 are included.[20] In the PLM model, α is set to 0.5 and γ equal to one. The estimates of these two parameters in the NPLM model will shed light on the degree of labour mobility across sectors and to what extent sector-specific disturbances will affect sectors asymmetrically.

2.4.2 Results

The key estimation results are presented in Table 2.3 and compare posterior distributions for the PLM and NPLM model.[21] Overall, posterior estimates of the structural parameters do not differ greatly across

[17] A variance decomposition and analysis of posterior impulse response functions led Rabanal (2009) to the conclusion that 'the Balassa-Samuelson effect does not appear to be an important driver of the inflation differential during the EMU period' for Spain because of a predicted fall in non-traded inflation in response to traded-sector productivity shocks. The variance decomposition he performed suggests that Spanish inflation variability was mostly driven by productivity shocks while output variability was mainly affected by demand disturbances.

[18] A summary can be found in Table 2.A1 in Appendix A.

[19] The identification analysis following Ratto & Iskrev (2011) suggests that the parameter governing habit is relatively weakly identified, which is why it is fixed to the mean of the prior analysis in Section 2.3. The results are not significantly affected if the calibration is changed.

[20] The prior distributions are summarised in table 2.A2 in Appendix A.

[21] A full table of the posterior results can be found in Table 2.A3 in Appendix A. Prior and posterior densities are displayed in Figures 2.B1 and 2.B2 in Appendix B.

the two models and confirm many earlier findings in the literature and those of Rabanal (2009). Calvo parameter estimates in the traded sector imply relatively flexible prices compared to the non-traded sector in both countries. Furthermore, as in Rabanal (2009), prices are less rigid in Spain than in the rest of the eurozone across both sectors. The degree of backward-looking behaviour in the Phillips curve measured by indexation is relatively low but estimated to be slightly higher in the PLM model.

Parameter	NPLM	PLM	Parameter	NPLM	PLM
θ_H	0.18	0.20	μ_H	0.44	0.51
	(0.08-0.28)	(0.10-0.30)		(0.12-0.74)	(0.17-0.87)
θ_F	0.32	0.29	μ_F	0.37	0.45
	(0.20-0.44)	(0.17-0.42)		(0.08-0.64)	(0.11-0.79)
θ_N	0.75	0.66	μ_N	0.22	0.22
	(0.67-0.83)	(0.57-0.75)		(0.03-0.39)	(0.04-0.38)
θ_{N^*}	0.88	0.83	μ_{N^*}	0.27	0.44
	(0.85-0.91)	(0.79-0.88)		(0.07-0.47)	(0.15-0.72)
α	0.63	0.5	$\sigma(\epsilon_T)$	0.27	0.39
	(0.48-0.78)	-		(0.18-0.38)	(0.24-0.53)
γ	2.33	1	$\sigma(\epsilon_{Z_T})$	0.54	0.71
	(1.75-2.94)	-		(0.39-0.67)	(0.53-0.90)
$\sigma(\epsilon_{Z_N})$	0.81	0.69	$\sigma(\epsilon_{Z_T^*})$	0.25	0.32
	(0.45-1.19)	(0.43-0.94)		(0.15-0.36)	(0.16-0.47)
$\sigma(\epsilon_{Z_N^*})$	0.77	0.70			
	(0.41-1.10)	(0.47-0.93)			
Log-L	18.22	-17.00			

Note: For each parameter I report the estimated posterior mean and 90% interval (in brackets) in the perfect labour mobility (PLM) and nesting perfect labour mobility (NPLM) model. The log-likelihood is based on the harmonic mean estimator.

Table 2.3: Key posterior distributions - Spain and rest of the EMU

The estimates for the parameters governing the degree of labour mobility, α and γ, suggest that labour is indeed not perfectly mobile across sectors. While the credible set of the weight of hours dedicated to the traded sector, α, still includes the PLM model value of 0.5, the estimate for the inverse elasticity of substitution of hours across sectors, γ, clearly rejects the hypothesis of perfect labour mobility across sectors ($\gamma = 1$), despite a very agnostic prior.

Estimated variances for traded-sector technology shocks are higher in the PLM model, while variances of non-traded-sector technology shocks are slightly lower. This should be due to the fact that the NPLM allows an asymmetric transmission of sector-specific productivity disturbances so that the relative size of sector-specific disturbances changes. The results in Table 2.3 suggest that in the NPLM, traded-sector productivity disturbances are relatively smaller compared to those in the non-traded sector.

The NPLM model clearly outperforms the PLM model in terms of fitting the data. The log Bayes factor, equal to the difference of the log-likelihoods of the two models, gives an indication as to which model is more strongly supported by the data. A log Bayes factor of about 35 heavily favours the NPLM model; in other words, allowing for imperfect labour mobility across sectors implies a much better fit to the data than restricting labour mobility to being perfect.

Figure 2.4 displays the posterior mean impulse responses of the real exchange rate and the price level of non-traded goods to a traded-sector productivity shock for the PLM (light grey) and NPLM (dark grey) model. At the posterior mean, the NPLM model predicts a rise in non-traded goods prices following an increase in traded-sector productivity, supporting a Balassa-Samuelson rationale, while the PLM model, unsurprisingly, predicts a fall in non-traded goods prices.[22]

At the posterior mean, a rise in traded-sector productivity in the NPLM model leads to a fall in traded-labour demand and the associated nominal wages. However, prices for traded goods drop as marginal costs fall so that overall real wages increase with the rise in productivity. Real labour income increases overall at the posterior mean estimates so that households seek to increase their consumption – in particular their consumption of the relatively cheap traded good. However, as final traded and non-traded goods are imperfectly substitutable, households also increase their demand for non-traded goods. Non-traded goods producers demand more labour, their marginal costs increase with production and non-traded goods prices increase. With equal sector wages, as in the PLM model, non-traded nominal wages would have fallen in line with nominal traded-sector wages and would thus not have led to a rise in marginal costs justifying higher non-traded goods prices.

However, this increase in non-traded goods prices in the NPLM model does not lead to an appreciation of the real exchange rate. In fact, the response of the real exchange rate to the traded-sector productivity shock is close to identical across the PLM and NPLM models and differs only in the response of non-traded goods prices. The depreciation in the NPLM model is the result of a strong terms of trade effect that outweighs the rise in non-traded goods prices. As discussed in the prior analysis, the terms of trade effect, which is roughly identical across the two models, favours a depreciation under home bias, as firms in the traded sector will always lower their prices in response to an increase in productivity and a decline in their marginal costs. Since the posterior estimate in the NPLM model for the elasticity of substitution of hours worked across sectors, γ, is still relatively close to one, the rise in non-traded goods prices is not strong enough to outweigh the terms of trade effect in the NPLM model. This leads to an overall depreciation

[22]The credible sets of posterior impulse responses of the PLM model include some positive responses of the price level of non-traded goods. This is because of the estimated potential high persistence of the traded-sector productivity shock given by the credible set in Table 2.A3 in Appendix A. As productivity shocks become close to permanent, the New Keynesian feature of sticky prices becomes irrelevant as we approach a classic long-run perspective in which price levels are higher where productivity levels are higher.

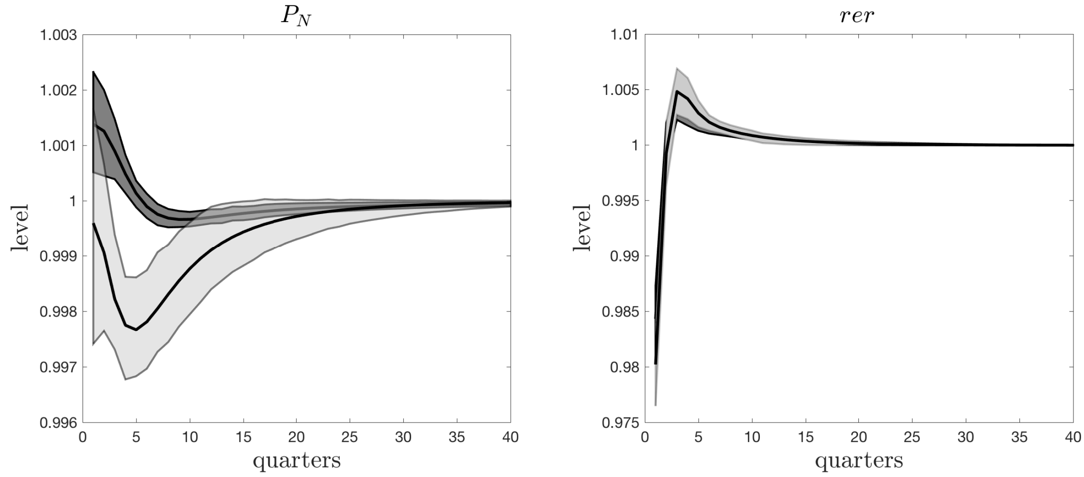


Figure 2.4: Posterior mean impulse response functions and 90% credible sets for a one standard deviation increase in traded-sector technology of the real exchange rate and the non-traded goods price level in Spain based on the PLM (light grey) and NPLM (dark grey) model

of the real exchange rate following the traded-sector productivity shock that is close to identical to the response in the PLM model.

These results stand in stark contrast to the conclusion of Rabanal (2009) that the 'Balassa-Samuelson effect fails to hold'. His posterior impulse response functions for the response of inflation in the non-traded sector to traded-sector productivity shocks clearly implied falling prices in the non-traded sector. As established in the prior analysis in Section 2.3, this has been the result of allowing for perfect labour mobility across sectors. While the overall effect on the real exchange rate remains negative across the two sectors, the NPLM model uncovers that non-traded goods prices do increase with traded-sector technology shocks mirroring a Balassa-Samuelson rationale.

Finally, key results of the variance decomposition of the observables are reported in Table 2.4.[23] It reports the differences in the contribution of shocks of the NPLM relative to the PLM; a negative value of x implies that the PLM model overestimates the contribution of that shock by x percentage points, as in the NPLM model the estimate is x percentage points lower. Note that country-specific shocks include domestic as well as foreign shocks that could potentially spill over to the other economy.

Allowing for imperfect intersectoral labour mobility adjusts in particular entries related to traded-sector technology shocks. Note that for aggregate country inflation rates and in particular the inflation differential, i.e. the change in the real exchange rate, country-specific traded-sector technology shocks contribute significantly less to the observed variability. This is in line with relatively smaller estimates of

[23]The full set of variance decompositions for the two models can be found in Table 2.A4 in Appendix A.

	Country-specific shocks				Area-wide shocks	
	Technology		Demand			
	Tradable	Nontradable	Tradable	Nontradable	Technology	Monetary
π	-8.36	-4.30	20.98	-1.26	1.04	-8.08
π_N	0.65	-5.94	2.54	8.98	1.18	-7.14
π^*	-2.07	-3.07	25.56	-1.62	-2.4	-16.40
π_N^*	0.67	-4.04	5.51	2.12	4.85	-9.11
ΔY	-14.55	-2.99	21.62	-2.11	-2.13	0.18
ΔY_N	0.59	4.29	1.15	-10.24	0.09	4.12
$\pi - \pi^*$	-16.62	-10.5	30.26	-3.09	0.08	-0.23

Note: Variance decomposition based on the parameter estimates of the nesting perfect labour mobility (NPLM) and the perfect labour mobility (PLM) model

Table 2.4: Differences between the variance decomposition of the NPLM and the PLM model (in percentage points) - Spain and the rest of the EMU

the variances of traded-sector productivity reported in Table 2.3. In the NPLM model, these variables are more significantly driven by demand disturbances in the traded sector, which contradicts the findings of Rabanal (2009) but strengthens the argument by López-Salido et al. (2005) that demand disturbances are responsible for Spanish inflation rates.[24]

Variability of non-traded inflation remains predominantly driven by non-traded productivity shocks, but the NPLM model assigns a higher weight to demand disturbances. Also, for aggregate output variability in Spain, a higher weight is assigned to demand disturbances relative to supply side factors. The opposite holds true for the variability of services GDP. Although more than 76% of the variability is still explained by non-traded demand disturbances, there is slightly more weight on non-traded technology shocks and monetary policy shocks.

Overall, the variance decomposition confirms the majority of Rabanal's (2009) findings but refines the relative contribution of shocks. First, technology shocks play a less decisive role for the variability of aggregate and non-traded inflation in both Spain and the rest of the EMU. Second, the contribution of demand disturbances to the variability of real exchange rate dynamics is significantly underestimated by more than 27% in the PLM model. Third, output variability remains mainly driven by demand disturbances as suggested by Rabanal (2009). However, while the PLM model underestimates the contribution of traded demand disturbances to aggregate output variability in Spain, the impact of non-traded demand disturbances on services GDP in Spain is slightly overestimated.

This section has shown that allowing for imperfect intersectoral labour mobility and the estimation

[24]This comparison should be taken with some caution, as López-Salido et al. (2005) consider a different time horizon and are predominantly concerned with the persistent differences in inflation rates rather than dynamics.

of nesting parameters i) delivers a significantly improved model-fit to the data, ii) uncovers a distinct asymmetric transmission mechanism of sector-specific productivity shocks, and iii) considerably corrects the relative contribution of shocks to the variability in observables.

2.5 Conclusion

In this paper, I show that the degree of intersectoral labour mobility is decisive for the transmission of sector-specific productivity disturbances and their effects on the real exchange rate. In particular, traded-sector productivity shocks necessarily lead to a depreciation of the real exchange rate under perfect labour mobility across sectors. This is because in New Keynesian models, labour demand falls in response to positive productivity shocks. When traded-sector productivity increases, firms in that sector lower their labour demand, leading to a fall in the economy-wide wage under equal sector wages due to perfect labour mobility. This causes marginal costs and hence prices to fall in the non-traded sector, which contradicts the rationale of a Balassa-Samuelson effect. Allowing for imperfect intersectoral labour mobility via a CES specification following Horvath (2000) enables the model to induce an appreciation of the real exchange rate due to an increase in non-traded goods prices. The parameters governing the degree of labour mobility deliver testable parameter restrictions for a Bayesian estimation of the model.

The application to Spanish inflation variability relative to the rest of the eurozone up to the GFC clearly rejects the hypothesis of perfect labour mobility across sectors. Impulse response functions at the posterior mean suggest that the Balassa-Samuelson rationale holds, i.e. that non-traded goods prices respond positively to traded-sector productivity shocks. Only a strong terms of trade effect hinders the rise in non-traded goods prices to lead to an overall appreciation. Comparing variance decompositions of the nesting perfect labour mobility (NPLM) and the perfect labour mobility (PLM) model shows that in the PLM model, the impact of technology (demand) shocks on inflation rate variability is significantly overestimated (underestimated). The conclusion by Rabanal (2009) that output variability was mainly driven by demand disturbances generally holds true.

Movements in the real exchange rate are a natural response to country-specific disturbances in a regime of fixed nominal exchange rates. A better understanding of the sources of those dynamics is of high interest to academics as well as policy makers. The analysis in this paper delivers a refined picture of the contribution of demand and supply disturbances to real exchange rate dynamics. In light of the ongoing debate concerning how much regional policy intervention is needed within the eurozone, the results from this analysis help to inform about potential fiscal targets or instruments that should be used for regional stabilisation.

2.A Appendix - Tables

Observable variable	Model counterpart
HICP inflation Spain	π_t
Services inflation Spain	$\pi_{N,t}$
HICP inflation rest of EMU	π^*_t
Services inflation rest of EMU	$\pi^*_{N,t}$
Real GDP growth Spain	ΔY_t
Services real GDP growth Spain	$\Delta Y_{N,t}$
Real GDP growth rest of EMU	ΔY^*_t
Services real GDP growth rest of EMU	$\Delta Y^*_{N,t}$
3-month T-bill rate	R_t

Note: The rest of the EMU comprises the euro area 18 excluding Spain. Data source: Eurostat.

Table 2.A1: Data

Description	Parameter	Distribution	Mean	Std. Dev.
Calvo parameter	$\theta_N, \theta_{N^*}, \theta_H, \theta_F$	Beta	0.75	0.15
Indexation	$\mu_N, \mu_{N^*}, \mu_H, \mu_F$	Beta	0.6	0.2
Monetary policy strength	ϕ	Normal	1.5	0.1
Interest rate rule persistence	ρ_R	Beta	0.7	0.1
Technology shock persistence	ρ_{Z_T}, ρ_{Z_N}	Beta	0.7	0.1
Demand shock persistence	ρ_{G_T}, ρ_{G_N}	Beta	0.7	0.1
Std. dev. technology shocks in %	$\sigma(\epsilon_{Z_S}), \sigma(\epsilon_T)$	Gamma	0.7	0.1
Std. dev. demand shocks in %	$\sigma(\epsilon_{G_S})$	Gamma	1	0.5
Std. dev. monetary shocks in %	$\sigma(\epsilon_M)$	Gamma	0.4	0.2
Weight on L_T in CES	α	Normal	0.5	0.1
Inverse elasticity of subst. between T and N hours	γ	uniform	5.5	$9/\sqrt{12}$

Note: Parameters α and γ are calibrated to 0.5 and 1 respectively in the perfect labour mobility (PLM) model. $S \in \{T, N, T^*, N^*\}$.

Table 2.A2: Priors - Spain and rest of the EMU

Parameter	NPLM	PLM	Parameter	NPLM	PLM
θ_H	0.18	0.20	μ_H	0.44	0.51
	(0.08-0.28)	(0.10-0.30)		(0.12-0.74)	(0.17-0.87)
θ_F	0.32	0.29	μ_F	0.37	0.45
	(0.20-0.44)	(0.17-0.42)		(0.08-0.64)	(0.11-0.79)
θ_N	0.75	0.66	μ_N	0.22	0.22
	(0.67-0.83)	(0.57-0.75)		(0.03-0.39)	(0.04-0.38)
θ_{N^*}	0.88	0.83	μ_{N^*}	0.27	0.44
	(0.85-0.91)	(0.79-0.88)		(0.07-0.47)	(0.15-0.72)
ρ_R	0.65	0.68	ϕ	1.47	1.52
	(0.58-0.72)	(0.59-0.76)		(1.31-1.63)	(1.36-1.68)
α	0.63	0.5	$\sigma(\epsilon_M)$	0.14	0.14
	(0.48-0.78)	-		(0.09-0.14)	(0.10-0.19)
γ	2.33	1	$\sigma(\epsilon_T)$	0.27	0.39
	(1.75-2.94)	-		(0.18-0.38)	(0.24-0.53)
ρ_{Z_T}	0.86	0.82	$\sigma(\epsilon_{Z_T})$	0.54	0.71
	(0.79-0.93)	(0.71-0.94)		(0.39-0.67)	(0.53-0.90)
ρ_{Z_N}	0.73	0.79	$\sigma(\epsilon_{Z_N})$	0.81	0.69
	(0.61-0.84)	(0.69-0.90)		(0.45-1.19)	(0.43-0.94)
ρ_{G_T}	0.79	0.79	$\sigma(\epsilon_{Z_T^*})$	0.25	0.32
	(0.74-0.85)	(0.73-0.86)		(0.15-0.36)	(0.16-0.47)
ρ_{G_N}	0.88	0.88	$\sigma(\epsilon_{Z_N^*})$	0.77	0.70
	(0.84-0.93)	(0.84-0.93)		(0.41-1.10)	(0.47-0.93)
$\sigma(\epsilon_{G_T})$	0.39	0.39	$\sigma(\epsilon_{G_N})$	0.19	0.21
	(0.29-0.48)	(0.31-0.45)		(0.14-0.24)	(0.17-0.24)
$\sigma(\epsilon_{G_T^*})$	0.36	0.36	$\sigma(\epsilon_{G_N^*})$	0.14	0.15
	(0.28-0.45)	(0.29-0.43)		(0.10-0.18)	(0.12-0.18)
Log-L	18.22	-17.00			

Note: For each parameter I report the estimated posterior mean and 90% interval (in brackets) in the perfect labour mobility (PLM) and nesting perfect labour mobility (NPLM) model. Log-likelihood based on the harmonic mean estimator.

Table 2.A3: Posterior distributions - Spain and rest of the EMU

	Country-specific shocks				Area-wide shocks	
	Technology		Demand			
	Tradable	Non-tradable	Tradable	Non-tradable	Technology	Monetary
π	27.46	4.89	28.15	1.15	18.14	20.23
	(35.82)	(9.19)	(7.17)	(2.41)	(17.10)	(28.31)
π_N	3.32	50.61	10.84	12.10	7.40	15.73
	(2.67)	(56.55)	(8.30)	(3.12)	(6.22)	(23.14)
π^*	7.39	1.29	41.66	0.34	27.00	22.33
	(9.46)	(4.36)	(16.10)	(1.96)	(29.40)	(38.73)
π_N^*	5.39	28.98	18.86	4.68	19.88	22.21
	(4.72)	(33.02)	(13.35)	(2.56)	(15.03)	(31.32)
ΔY	22.05	1.13	57.44	11.64	6.88	0.87
	(36.60)	(4.12)	(35.82)	(13.75)	(9.01)	(0.69)
ΔY_N	1.56	10.78	1.96	76.80	0.38	8.53
	(0.97)	(6.49)	(0.81)	(87.04)	(0.29)	(4.41)
ΔY^*	2.58	0.47	75.81	9.67	8.54	2.92
	(3.02)	(2.07)	(74.30)	(10.20)	(8.53)	(1.89)
ΔY_N^*	0.28	5.41	0.70	74.24	0.99	18.39
	(0.23)	(3.24)	(0.86)	(84.09)	(0.68)	(10.91)
R	8.94	2.11	39.74	0.49	33.34	15.37
	(12.96)	(7.56)	(20.02)	(3.22)	(41.60)	(14.63)
$\pi - \pi^*$	40.83	7.93	47.54	1.76	0.54	1.41
	(57.35)	(18.43)	(17.28)	(4.85)	(0.46)	(1.64)

Note: Variance decomposition based on the parameter estimates of the nesting perfect labour mobility (NPLM) model (perfect labour mobility (PLM) model in brackets)

Table 2.A4: Variance decomposition (in percent) - Spain and the rest of the EMU

2.B Appendix - Figures

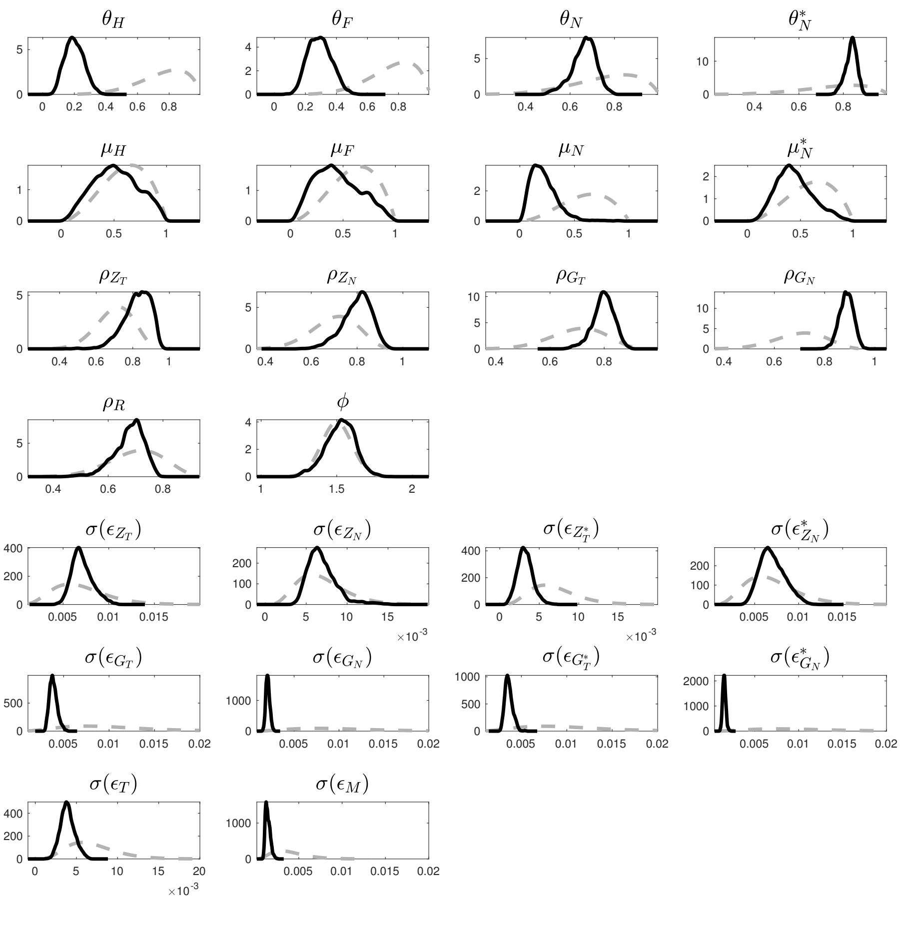


Figure 2.B1: Prior (dashed) and posterior (solid) denisities for the structural parameters based on the estimation of the perfect labour mobility (PLM) model

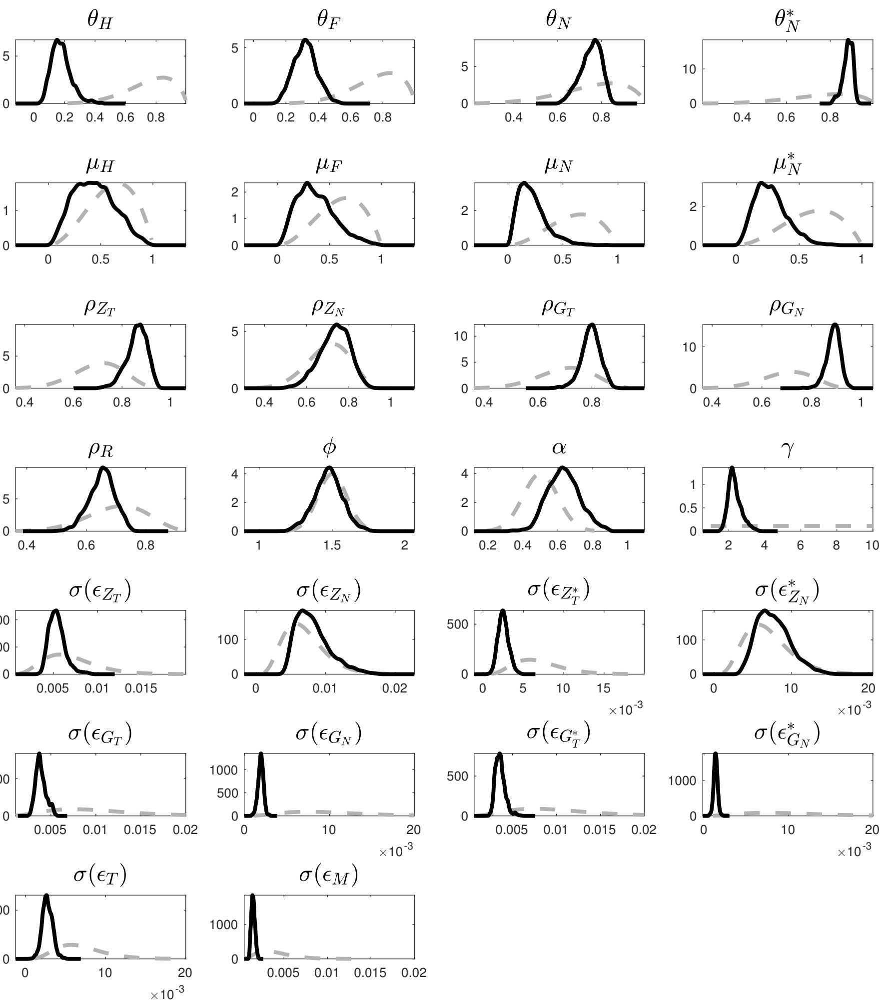


Figure 2.B2: Prior (grey, dashed) and posterior (black, solid) denisities for the structural parameters based on the estimation of the nesting perfect labour mobility (NPLM) model

THIRD ESSAY

Budget-neutral fiscal rules targeting inflation differentials

In light of persistent inflation dispersion and high debt levels in the EMU, this paper investigates the desirability of budget-neutral fiscal policy rules that respond to the domestic inflation differential. The paper employs a two-country DSGE model of a monetary union with traded and non-traded goods. When consumption or labour income taxes respond to the domestic inflation differential while lump-sum taxes balance the budget, a national fiscal authority is able to reduce welfare costs of business cycle fluctuations by 1-4%. In the absence of lump-sum taxes, hybrid rules using only distortionary taxes can reduce welfare costs by 6-10% under demand and supply disturbances. Gains in welfare stem from higher mean consumption due to lower price dispersion when the fiscal authority actively compresses the domestic inflation differential and thus domestic inflation.

3.1 Introduction

During the 2000s, European countries' inflation rates were characterised by a rising degree of heterogeneity. Prior to the introduction of the euro, countries with traditionally higher inflation rates managed to lower them in order to comply with the Maastricht criteria. In the early years of the euro, it appeared that nominal convergence had been attained.[1] However, as documented by Rabanal (2009), the following years showed a reversal in this trend. Specifically, inflation rates in the southern European periphery consistently exceeded the average euro area inflation rate, leading to significant real appreciations and the often-mentioned loss of competitiveness.

Deviations of the domestic inflation rate from the union-wide average, or in other words, inflation differentials, are not necessarily an undesirable phenomenon in a monetary union. Since the nominal exchange rate is fixed, inflation differentials are the natural by-product of asymmetric shocks and part of the adjustment mechanism. They do pose a problem, however, for the conduct of monetary policy. Let us consider a country whose inflation rate is above that of the union as a whole. The nominal interest rate set by the centralised monetary authority does not increase as much as the Taylor principle would prescribe. The country's inflation rate enters the aggregate union-wide inflation rate with a certain weight so that the Central Bank only partially responds to the increase in inflation in that country, a fact commonly referred to as 'one size does not fit all'.

Moreover, inflation differentials are particularly problematic if they are highly persistent, as observed in the euro area after the introduction of the euro. The persistent deviations from the union-wide inflation rate lead to a large divergence in competitiveness and are followed by a harmful readjustment period for the countries whose real exchange rate has strongly appreciated.[2] As a centralised monetary policy cannot address the heterogeneity across member countries' inflation rates, various papers have asked what role could be assigned to national fiscal policies in mitigating differences in inflation rates and to what extent such a policy would be desirable.

This paper seeks to add to the existing discussion on fiscal feedback to national differences by analysing the effectiveness of fiscal tax rules that strategically react to the domestic inflation differential

[1] See Rogers (2007), who argues that nominal convergence across the euro area was achieved already in the '90s.

[2] A large amount of research has been dedicated to identifying the drivers of inflation differentials across the EMU countries. Prominent hypotheses are a catching-up process, as described in Balassa (1964) and Samuelson (1964); differences in institutions/rigidities; and demand-driven effects. A non-exhaustive overview of research in this field includes López-Salido et al. (2005), Canzoneri et al. (2006), Angeloni & Ehrmann (2007), Andrés et al. (2008), Rabanal (2009), Altissimo et al. (2011), and Morsy & Jaumotte (2012).

as a stabilising policy.[3] Kirsanova et al. (2007) find that fiscal feedback to differences in inflation rates are welfare-improving compared to fiscal rules responding to domestic output or the terms of trade only. In their New Keynesian model of a monetary union with two countries, feedback comes through government spending which is financed by government debt and constant taxes on labour income. Similarly, Beetsma & Jensen (2005) work with government purchases as the fiscal instrument financed by either lump-sum taxes or government debt. Furthermore, Vogel et al. (2013) study various tax instruments which also allow for government debt in their fiscal rules. Both analyses find gains from responding to deviations in the terms of trade.

Positive analyses by Duarte & Wolman (2002, 2008) add to the discussion by including a non-tradable goods sector in the model of the monetary union. Their inclusion of non-traded varieties extends the scope for large and persistent price and thus inflation differentials. The authors show that a fiscal authority can successfully compress inflation differentials using a fiscal rule for 'pro-cyclical' labour income taxes. A labour income tax that is lowered in response to a positive domestic inflation differential, i.e. when the domestic inflation rate is above the union-wide average, compresses inflation differentials, although the volatility of domestic inflation might increase.

The existing studies focus on non-distortionary instruments and allow the issuance of public debt to finance the fiscal intervention. In the European context, however, it is particularly interesting to inspect budget-neutral fiscal rules that abstract from issuing new public debt. The southern periphery of the euro area experienced a rise in the levels of public debt, rendering debt-financed policies that target inflation differentials potentially unattainable. Thus, this paper adds to the existing literature by explicitly considering budget-neutral policies and continues along the lines of a large body of research studying the optimal conduct of fiscal policy via simple rules in a monetary union.[4]

Furthermore, this paper is related to the literature concerned with fiscal devaluations, as it considers budget-neutral policies which became explicitly relevant in the context of the European debt crisis. Prominent works in this field by von Thadden & Lipinska (2013), Farhi et al. (2014), and Engler et al. (2014) investigate the effectiveness of a unilateral tax shift to boost competitiveness of a member country of a monetary union. The distinguishing aspect of the analysis performed in this paper compared to the existing literature on fiscal devaluations is this paper's focus on temporary tax shifts in response to con-

[3]Considering the inflation differential, i.e. the difference between a country's domestic inflation and that of the union, as the fiscal target has the simple advantage that it is easy to measure in a monetary union with several member states. Indicators such as terms of trade or differences in inflation rates are more difficult to apply in a framework of more than two countries such as the EMU.

[4]In addition to the works mentioned above, one should name Lombardo & Sutherland (2004), Beetsma & Jensen (2004, 2005), Pappa & Vassilatos (2007), Gali & Monacelli (2008), Ferrero (2009), and Kirsanova & Wren-Lewis (2012) as notable advances in this research area. In the European context, Evers (2012), Evers (2015), and Werning & Farhi (2012) among others have analysed the desirability of fiscal unions.

temporaneous discrepancies in the domestic and the union-wide inflation rate instead of permanent tax shifts.

Specifically, this paper analyses the effectiveness of four fiscal rules in reducing welfare costs arising from business cycle fluctuations. The tax instruments considered by the analysis are consumption, labour income, and lump-sum taxes that potentially balance the fiscal budget. Consumption taxes in the form of value-added taxes were one of the primary fiscal instruments to be adjusted during the global financial as well as the European crisis in several European countries and thus represent an obvious candidate for a fiscal tax rule to examine. This paper also considers labour income taxes and determines the benefits of using this instrument as suggested but not quantified by Duarte & Wolman (2008).

The welfare analysis suggests that consumption (labour income) taxes should be raised (lowered) when domestic inflation exceeds the union-wide average. Second, the fiscal rules for which lump-sum taxes balance the budget are able to reduce welfare costs of business cycle fluctuations by 1-4%. They do so by reducing the volatility of the inflation differential and domestic inflation, which lowers mean price dispersion and raises mean consumption. Interestingly, hybrid rules in which the fiscal budget is balanced by a distortionary tax outperform the rules relying on lump-sum financing and reduce welfare costs by 6-10% under the full stochastic setup. This is because they can combine the benefits of the rules relying on lump-sum financing, when the two tax instruments move in opposite directions. By doing so, inflationary responses are compressed most effectively.

The paper proceeds as follows: Section 3.2 presents the setup of the model and the channels through which inflation differentials arise. After declaring the baseline calibration in Section 3.3, Section 3.4 performs a welfare analysis for the four fiscal rules which are investigated. This section also presents the welfare gains or losses from the fiscal rules conditional on the shock specification and discusses impulse-response functions to compare the dynamics of the model under the different fiscal rules to the baseline in which distortionary taxes are constant. Section 3.5 concludes.

3.2 The model

The model is similar to that of Duarte & Wolman (2008) and consists of two countries of equal size, home (H) and foreign (F), which constitute a monetary union. Each country is populated by a measure one of households which have access to an internationally traded asset. In each country there is a sector producing tradable goods which are traded within the monetary union. There is also a sector producing non-tradable goods, which can only be consumed by domestic households and the domestic government. Both countries are subject to nominal rigidities in the goods market in both sectors. The model abstracts from migration, i.e. labour is immobile across countries. Within a country, however, labour is assumed to be perfectly mobile across sectors.

The following paragraphs describe the setup of the home economy. The structure of the foreign economy is analogous if not explicitly stated otherwise. Foreign variables are denoted by an asterisk.

3.2.1 Households

Households maximise their expected lifetime utility,

$$\mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \left[U(C_{t+k}) - V(L_{t+k}) \right] \quad , \tag{3.1}$$

where $\mathbb{E}$ denotes the expectations operator and $\beta \in (0, 1)$ the discount factor. Households derive utility from consumption, C_t, and disutility from supplying labour, L_t.

The aggregate consumption index, C_t, is composed of consumption of tradable, $C_{T,t}$, and non-tradable, $C_{N,t}$, goods, as in

$$C_t = \left[(1-\delta)^{\frac{1}{\iota}} C_{T,t}^{\frac{\iota-1}{\iota}} + \delta^{\frac{1}{\iota}} C_{N,t}^{\frac{\iota-1}{\iota}} \right]^{\frac{\iota}{\iota-1}} . \tag{3.2}$$

The elasticity of substitution between traded and non-traded goods is expressed by ι, while δ denotes the steady-state share of non-tradable goods in the aggregate consumption index. The price of the final consumption good is given by

$$P_t = \left[(1-\delta) P_{T,t}^{1-\iota} + \delta P_{N,t}^{1-\iota} \right]^{\frac{1}{1-\iota}} \quad , \tag{3.3}$$

where $P_{T,t}$ and $P_{N,t}$ denote the prices of traded and non-traded goods respectively.

Households choose the optimal allocation of consumption expenditures across different types of goods. The optimisation yields the following demand functions

$$C_{T,t} = (1-\delta) \left(\frac{P_{T,t}}{P_t} \right)^{-\iota} C_t \quad \text{and} \tag{3.4}$$

$$C_{N,t} = \delta \left(\frac{P_{N,t}}{P_t} \right)^{-\iota} C_t \quad . \tag{3.5}$$

Households have access to a riskless internationally traded bond, B_t, which pays out the gross nominal interest rate, R_t, in $t+1$. In line with von Thadden & Lipinska (2013), households pay a consumption tax, τ_t^C, on their consumption; a labour income tax, τ_t^L, on their labour income; and lump-sum taxes denoted by τ_t^{lump}. The intertemporal budget constraint expressed in real terms is given by

$$(1+\tau_t^C)C_t + \frac{B_t}{P_t} = R_{t-1}\frac{B_{t-1}}{P_t} + \Pi_t + (1-\tau_t^L)w_t L_t - \tau_t^{lump} \quad , \tag{3.6}$$

where w_t stands for the real wage in the economy and Π_t for profit transfers from the ownership of domestic firms. The wage is identical across sectors within the economy due to the assumption of perfect labour mobility across sectors and the absence of wage rigidities.

The optimal paths of C_t and L_t are described by the set of optimality conditions derived from the household's utility maximisation problem. The labour supply decision and the intertemporal Euler equation are given by

$$\frac{(1-\tau_t^L)W_t}{(1+\tau_t^C)P_t} = \frac{V'(L_t)}{U'(C_t)} \quad \text{and} \tag{3.7}$$

$$U'(C_t) = \beta\mathbb{E}_t\left[U'(C_{t+1})\frac{R_t}{\pi_{t+1}}\frac{1+\tau_t^C}{1+\tau_{t+1}^C}\right] \quad , \tag{3.8}$$

where $\pi_{t+1} = \frac{P_{t+1}}{P_t}$ denotes gross consumer price inflation net of taxes.

3.2.2 Firms

In both sectors, intermediate goods are produced by monopolistically competitive firms. Retailers use intermediate varieties as input for the production of final goods.

Retailers

The retail sector is characterised by perfect competition. Retail firms combine intermediate goods to produce the final good of their respective sector. In the non-traded sector, the final good, $Y_{N,t}$, is produced with technology $Y_{N,t} = \left(\int_0^1 Y_{N,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}$, where ϵ is the elasticity of substitution across different varieties, $Y_N(i)$, of the non-tradable good. Retailers in the non-traded sector maximise their profit

$$\max P_{N,t}Y_{N,t} - \int_0^1 P_{N,t}(i)Y_{N,t}(i)di \tag{3.9}$$

given their production technology, which yields the demand function

$$Y_{N,t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t}}\right)^{-\epsilon} Y_{N,t} \quad , \tag{3.10}$$

where $P_{N,t}(i)$ is the price for variety i of the non-traded good and $P_{N,t} = \left(\int_0^1 P_{N,t}(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$.

Retailers producing the final traded good, $Y_{T,t}$, combine intermediate home- and imported foreign-produced traded goods, $Y_{H,t}(i)$ and $Y_{F,t}(i)$. They maximise their profits according to

$$\max P_{T,t}Y_{T,t} - \int_0^1 P_{H,t}(i)Y_{H,t}(i)di - \int_0^1 P_{F,t}(i)Y_{F,t}(i)di \tag{3.11}$$

subject to technologies

$$Y_{T,t} = \left[(1-\omega)^{\frac{1}{\varphi}} Y_{H,t}^{\frac{\varphi-1}{\varphi}} + \omega^{\frac{1}{\varphi}} Y_{F,t}^{\frac{\varphi-1}{\varphi}}\right]^{\frac{\varphi}{\varphi-1}} \quad , \tag{3.12}$$

$$Y_{H,t} = \left(\int_0^1 Y_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \quad \text{and} \tag{3.13}$$

$$Y_{F,t} = \left(\int_0^1 Y_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \quad , \tag{3.14}$$

where φ is the elasticity of substitution between final home and foreign traded goods in the production of Y_T, and ω denotes the steady-state share of imported goods in the final traded good. An $\omega < 0.5$ implies home bias. The demand functions resulting from the profit maximisation read

$$Y_{H,t}^d(i) = (1-\omega)\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon}\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\varphi} Y_{T,t} \quad \text{and} \tag{3.15}$$

$$Y_{F,t}^d(i) = \omega\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon}\left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\varphi} Y_{T,t} \quad , \tag{3.16}$$

where $P_{H,t}(i)$ and $P_{F,t}(i)$ are the prices of the home and foreign traded variety i and where the price indices are defined as $P_{H,t} = \left(\int_0^1 P_{H,t}(i)^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$, $P_{F,t} = \left(\int_0^1 P_{F,t}(i)^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$, and $P_{T,t} = \left[(1-\omega)P_{H,t}^{1-\varphi} + \omega P_{F,t}^{1-\varphi}\right]^{\frac{1}{1-\varphi}}$.

Intermediate-goods producers

In each sector there is a continuum of monopolistically competitive firms, indexed by $i \in [0,1]$, which set their prices in a Calvo fashion. Given linear production technologies, firms produce intermediate-goods varieties. The technologies, $Z_{S,t}$, are sector- and country-specific, where $S \in \{T, N\}$.

An intermediate-goods producer i produces non-tradable intermediate varieties with

$$Y_{N,t}(i) = \exp(Z_{N,t})L_{N,t}(i) \tag{3.17}$$

and seeks to maximise its expected profit given that with probability θ the firm will not be able to adjust its price, $P_{N,t}(i)$, in a given period. The optimisation problem solves

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} \left[Y_{N,t+k|t}(i) P_{N,t}(i) - W_{t+k} L_{N,t+k}(i) \right] \quad , \tag{3.18}$$

where $Q_{t,t+k} = \beta^k \frac{U'(C_{t+k})}{U'(C_t)} \frac{P_t}{P_{t+k}} \frac{1+\tau_t^C}{1+\tau_{t+k}^C}$ is the stochastic discount factor, $Y_{N,t+k|t}(i)$ output of firm i in $t+k$ given the price set in t, and W_t the nominal wage.

Similarly, intermediate traded goods produced in the home economy by firm i derive from the production function

$$Y_{H,t}(i) = \exp(Z_{T,t}) L_{T,t}(i) \quad . \tag{3.19}$$

This firm sets its price, $P_{H,t}(i)$, for home-produced traded varieties to maximise

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} \left[Y_{H,t+k|t}(i) P_{H,t}(i) - W_{t+k} L_{T,t+k}(i) \right] \tag{3.20}$$

given that with probability θ it cannot readjust its price.

Terms of trade

Incorporating non-traded goods in the model results in two measures of competitiveness, the external and the internal terms of trade. The (external) terms of trade, T_t, relate the price of foreign-produced traded goods to the price of home-produced traded goods, i.e.

$$T_t = \frac{P_{F,t}}{P_{H,t}} \quad . \tag{3.21}$$

The trade position of the home economy improves when the terms of trade increase, because domestically-produced traded goods become relatively cheaper. The internal terms of trade, $T_{N,t}$, are defined as

$$T_{N,t} = \frac{P_{N,t}}{P_{T,t}} \quad \text{and} \tag{3.22}$$

$$T_{N,t}^* = \frac{P_{N,t}^*}{P_{T,t}^*} \tag{3.23}$$

and deliver a measure for the competitiveness of the traded sector relative to the non-traded sector within an economy.

3.2.3 Policy makers

Central monetary authority

Monetary policy is conducted at the union-level. Following von Thadden & Lipinska (2013), the central bank sets the union-wide gross nominal interest rate, R_t, in response to the union-wide average consumer price inflation net of taxes, $\pi_t^U = (\pi_t)^{0.5}(\pi_t^*)^{0.5}$. The monetary policy rule à la Taylor (1993) reads

$$R_t = \frac{1}{\beta}\left(\pi_t^U\right)^{\phi} \quad , \tag{3.24}$$

where ϕ captures the 'hawkishness' of the central bank, i.e. how strongly the central bank reacts to inflation deviations.

Fiscal authority

In both countries the government consumes non-tradable goods. The stream of public consumption relative to total GDP within a country follows an exogenous AR(1) process of the form

$$(G_t/Y_t) = (\bar{G}/\bar{Y}) + \rho_g(G_{t-1}/Y_{t-1}) + \epsilon_{G,t} \quad , \tag{3.25}$$

where $|\rho_G| < 1$ and $\epsilon_{G,t} \sim \mathcal{N}(0, \sigma_G^2)$. The government uses its available tax income to finance its expenditures. The fiscal authority's budget constraint reads

$$\tau_t^{lump} + \tau_t^C C_t + \tau_t^L w_t L_t = G_t \quad . \tag{3.26}$$

The analysis is concerned with quantifying the welfare gains when the home economy strategically reacts to variations in its domestic inflation differential with one of its available tax instruments. In order to identify the effects of a specific fiscal rule of the home economy, it is assumed that the foreign economy keeps its distortionary taxes constant. That is, the budget of the foreign fiscal authority is balanced by lump-sum taxes so that the budget constraint of the foreign government reads

$$\tau_t^{*lump} + \bar{\tau}^{*C} C_t^* + \bar{\tau}^{*L} w_t^* L_t^* = G_t^* \quad , \tag{3.27}$$

where bar-variables denote deterministic steady-state values.

3.2.4 Market clearing and equilibrium

The market-clearing conditions for traded and non-traded goods, the labour market, and the international bond market are given by

$$
\begin{aligned}
Y_{T,t} &= C_{T,t} \quad , & (3.28)\\
Y_{N,t} &= C_{N,t} + G_t \quad , & (3.29)\\
L_t &= \int_0^1 L_{T,t}(i) + L_{N,t}(i)di \quad \text{and} & (3.30)\\
B_t &= -B_t^* \quad . & (3.31)
\end{aligned}
$$

To close the model, a debt-elastic interest rate as proposed by Schmitt-Grohé & Uribe (2003) is incorporated to induce stationarity on private debt. For the impulse response functions the model is approximated linearly around a zero-inflation steady state.

3.2.5 Sources of inflation differentials

Using the definition of the price of consumption in H, P_t, and its analogue for country F, P_t^*, one can analyse the different sources of consumer price differentials, which cause differences in inflation rates. First, the ratio of aggregate consumer prices of both countries is given by

$$
\frac{P_t}{P_t^*} = \frac{P_{T,t}}{P_{T,t}^*}\left[\frac{1-\delta+\delta T_{N,t}^{1-\iota}}{1-\delta+\delta T_{N,t}^{*1-\iota}}\right]^{\frac{1}{1-\iota}} \quad . \tag{3.32}
$$

Ignoring the ratio of traded goods prices for a moment, it is easily seen that the presence of non-traded goods ($\delta > 0$) is an essential ingredient of price (inflation) differentials. Non-traded goods prices are not in direct competition across countries. Hence, different prices for non-tradable goods translate into differing internal terms of trade across countries. These lead to price differentials even if the price indices for the final traded good are identical across countries, i.e. $P_{T,t} = P_{T,t}^*$.

Going one step further, one can analyse to what extent inflation differentials might arise from the traded goods sector. One can express the ratio of traded goods prices as

$$
\frac{P_{T,t}}{P_{T,t}^*} = \left[\frac{(1-\omega)P_{H,t}^{1-\varphi} + \omega P_{F,t}^{1-\varphi}}{(1-\omega)P_{F,t}^{1-\varphi} + \omega P_{H,t}^{1-\varphi}}\right]^{\frac{1}{1-\varphi}} \quad , \tag{3.33}
$$

which shows to what extent the presence of home or foreign bias is essential in creating price differentials.

Under $\omega = 0.5$, when home bias is absent, traded goods price indices are identical across countries. When $\omega \neq 0.5$, price (and inflation) differentials arise from the external terms of trade, i.e. the relative price of foreign to home-produced traded goods. Note that neither of the two channels described above rely on the inclusion of rigid prices.

3.3 Calibration

This section presents the benchmark parameter values of the model. The calibration is symmetric across countries and one model period corresponds to one quarter.

3.3.1 Private sector

The household's utility is governed by

$$U(C_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} \quad \text{and} \tag{3.34}$$

$$V(L_t) = \frac{L_t^{1+\kappa}}{1+\kappa} \quad , \tag{3.35}$$

where σ denotes the coefficient of relative risk aversion and κ the inverse of the Frisch elasticity of labour supply. The discount factor, β, takes a standard value of 0.99, while the coefficient of relative risk aversion, σ, as well as the inverse of the Frisch elasticity of labour supply, κ, is set to one (log-utility in consumption).

As in Duarte & Wolman (2008), the share of non-tradable goods in the consumption basket, δ, takes a value of 0.4 and the elasticities of substitution, ι, φ, and ϵ, are set to 0.74, 1.5, and 10 respectively. In contrast to these authors, the calibration allows for home bias in the production of the final traded good and sets $\omega = 0.4$.

The Calvo parameter, θ, is assumed to be identical across sectors and countries. The expected price lifetime is 3 quarters such that $\theta = 2/3$, which is close to estimates by Druant et al. (2012), who find for a sample of 17 European countries that, on average, prices remain unchanged for around 10 months.

3.3.2 Public sector

Monetary policy is characterised by a standard Taylor coefficient of $\phi = 1.5$. For the fiscal side, this work follows von Thadden & Lipinska (2013) and Duarte & Wolman (2008) by assuming a steady-state consumption tax rate, $\bar{\tau}^C$, of 15% and a steady-state labour income tax rate, $\bar{\tau}^L$, of 18%. In order to comply with the budget constraint of the government, the steady-state share of public consumption relative to domestic GDP is set to 27.13%.

3.3.3 Shock processes

The analysis uses the estimated shock processes and variance-covariance matrices of Duarte & Wolman (2008) for the technology and government spending processes. Technology shocks follow an AR(1) process, $Z_t = AZ_{t-1} + \epsilon_{Z,t}$, with covariance matrix Ω, where $Z_t = [Z_{T,t}, Z_{N,t}, Z^*_{T,t}, Z^*_{N,t}]$,

$$A = \begin{pmatrix} 0.708 & 0.169 & 0.006 & -0.435 \\ -0.023 & 0.707 & -0.061 & -0.038 \\ 0.006 & -0.435 & 0.708 & 0.169 \\ -0.061 & -0.038 & -0.023 & 0.707 \end{pmatrix} \quad , \tag{3.36}$$

and

$$\Omega = \begin{pmatrix} 0.16 & 0.05 & 0.03 & 0 \\ 0.05 & 0.06 & 0 & 0 \\ 0.03 & 0 & 0.16 & 0.05 \\ 0 & 0 & 0.05 & 0.06 \end{pmatrix} \times 10^{-3} \quad . \tag{3.37}$$

Shocks to the share of government consumption of output follow independent AR(1) processes with persistence, ρ_g, of 0.42 and variance $\sigma^2_G = 2.14 \times 10^{-4}$.

3.4 Welfare analysis

In order to understand whether a fiscal tax rule that responds to the domestic inflation differential can be welfare-improving, this section determines and compares the welfare costs of business cycle fluctuations under different tax regimes for a given union-wide monetary policy.

The welfare analysis follows the framework of Lucas (1987, 2003) and computes the consumption compensation, v, that a household would be willing to pay to avoid moving from the deterministic steady state to the stochastic environment. Formally, the consumption compensation, v, solves

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^t[U(C_t) - V(L_t)] = \sum_{t=0}^{\infty}\beta^t[U((1+v)\bar{C}) - V(\bar{L})] \quad , \tag{3.38}$$

where bar-variables denote the deterministic steady state of the model variables.

The unconditional expectation of the household's lifetime utility in the ergodic distribution of the model must be equal to the lifetime utility of the household in the deterministic steady state paying the consumption compensation, v. Using a second-order Taylor approximation on both sides, one can express v as a function of first- and second-order moments of the ergodic distribution of consumption and hours. v can be decomposed into four components

$$v = v_{meanC} + v_{meanL} + v_{volatilityC} + v_{volatilityL} \quad , \tag{3.39}$$

which allows the inspection of contributions of mean effects that capture the difference between the mean in the ergodic distribution of the model and the deterministic steady state, v_{meanC} and v_{meanL}, and volatility effects, $v_{volatilityC}$ and $v_{volatilityL}$. In order to accurately calculate the moments of the ergodic distribution, the model is written recursively and solved in Dynare using a second-order accurate perturbation. This paper employs the method developed by Lan & Meyer-Gohde (2013) to find accurate first- and second-order moments analytically.

The analysis considers four tax regimes of fiscal feedback to the domestic inflation differential: a responsive consumption or labour income tax where the fiscal budget is balanced by lump-sum taxes, (1) and (2), or when the fiscal budget has to be balanced by the remaining distortionary tax, (3) and (4). The regimes take the following forms

(1) $\tau_t^L = \bar{\tau}^L$ and $\tau_t^C = \bar{\tau}^C + \zeta\left(\ln \pi_t - \ln \pi_t^U\right)$

(2) $\tau_t^C = \bar{\tau}^C$ and $\tau_t^L = \bar{\tau}^L + \zeta\left(\ln \pi_t - \ln \pi_t^U\right)$

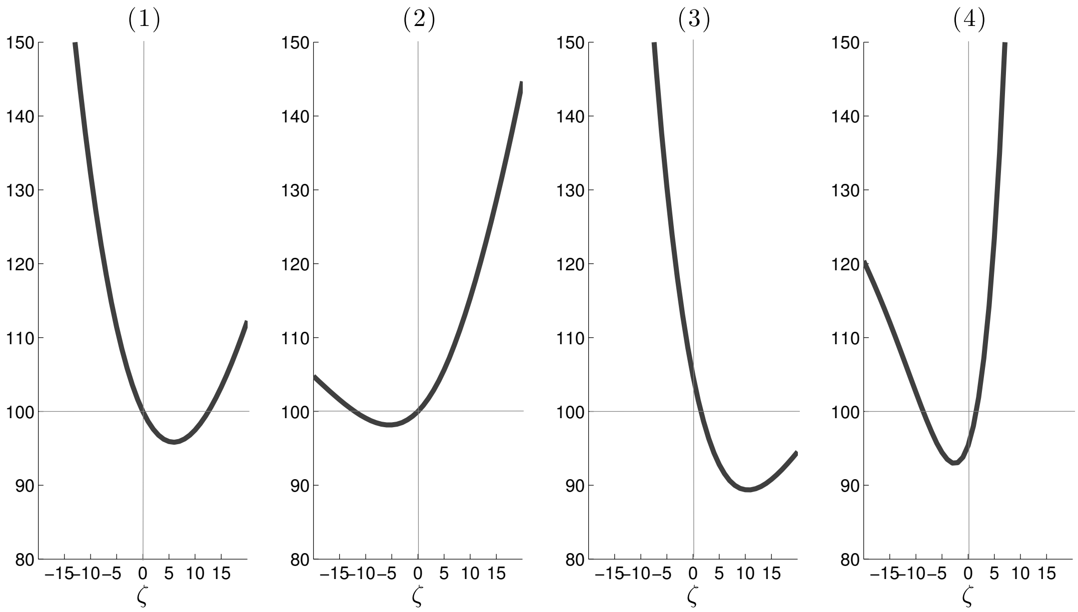
(3) $\tau_t^{lump} = 0$ and $\tau_t^C = \bar{\tau}^C + \zeta\left(\ln \pi_t - \ln \pi_t^U\right)$

(4) $\tau_t^{lump} = 0$ and $\tau_t^L = \bar{\tau}^L + \zeta\left(\ln \pi_t - \ln \pi_t^U\right)$

where ζ denotes the elasticity of the tax rate with respect to the inflation differential $\left(\ln \pi_t - \ln \pi_t^U\right)$, i.e. when domestic inflation is one percentage point above the union-wide aggregate the tax rate increases by ζ percentage points.

These four regimes are compared to a baseline economy with $\zeta = 0$, i.e. with constant distortionary taxes, and where the fiscal budget is balanced by lump-sum taxes to evaluate the desirability of the fiscal rules. The analysis varies the policy parameter ζ over a grid and searches for the ζ at which welfare losses are minimised relative to the benchmark.

Figure 3.1 displays the welfare costs of business cycle fluctuations for different ζ relative to the baseline scenario. For each scenario there exists a point at which welfare losses are minimised relative to



Note: Rules (3) and (4) do not cross the benchmark intersection at $\zeta = 0$ because they abstract from lump-sum taxes. For instance, for Rule (3) when consumption taxes are constant at $\zeta = 0$ labour income taxes have to balance the fiscal budget and vice versa. The fluctuations of the distortionary labour income tax cause different welfare costs than if lump-sum taxes would balance the budget. As a consequence, at $\zeta = 0$ welfare costs of Rule (3) and (4) are different from 100.

Figure 3.1: Welfare costs of business cycle fluctuations for different values of ζ relative to constant distortionary taxes when the budget is financed exclusively by lump-sum taxes (=100) for rules (1)-(4)

constant distortionary taxes. Rules (1) and (3) display a minimum at positive values for ζ, i.e. ideally the consumption tax should be raised in response to a domestic inflation rate that is above the union average. The optima of rules (2) and (4), on the other hand, are attained at a negative value for ζ, which is in line with the analysis by Duarte & Wolman (2008), who discuss a pro-cyclical labour income tax. Ideally, labour income taxes should be lowered in response to a positive domestic inflation differential.

Table 3.1 displays the gains of the fiscal rules relative to the baseline at their respective optimum, ζ^*, for the four different scenarios.[5] In all cases the majority of the welfare costs arise in the mean component of consumption, v_{meanC}, due to the difference between mean consumption in the ergodic distribution of the model and the level of consumption in the deterministic steady state. The welfare costs in the mean component of consumption, i.e. the difference between the unconditional expectation of consumption in the ergodic distribution and its deterministic steady state, arise as follows. Following an exogenous disturbance, only a fraction of firms can adjust their prices due to the Calvo-pricing mechanism.

[5]Note that the optimal tax elasticities seem rather high, especially for Rule (3). This is largely explained by the model setup considering two countries *of equal size*. In order to create an inflation differential of 1%, the model needs strong variations in the domestic inflation rate, as the union-wide aggregate partly comoves with domestic inflation, *ceteris paribus*. The large disturbances necessary to create such sizeable inflation differentials justify the size of the optimal tax elasticities.

		(1) ($\zeta^* = 6$)		(2) ($\zeta^* = -5$)		(3) ($\zeta^* = 11$)		(4) ($\zeta^* = -3$)	
	baseline	responsive	Δ%	responsive	Δ%	responsive	Δ%	responsive	Δ%
Welfare loss of fluctuations	-1.0378	-0.9945	4.17	-1.0188	1.83	-0.9276	10.62	-0.9652	6.99
Decomposition:									
v_{meanC}:	-0.7694	-0.6787	8.74	-0.6845	8.17	-0.7435	2.50	-0.6451	11.98
v_{meanL}:	-0.0825	-0.1375	-5.30	-0.1344	-5.00	0.0047	8.40	-0.0100	6.99
$v_{volatilityC}$:	-0.0422	-0.0696	-2.63	-0.0446	-0.23	-0.1515	-10.52	-0.2930	-24.16
$v_{volatilityL}$:	-0.1437	-0.1087	3.36	-0.1552	-1.11	-0.0373	10.25	-0.0172	12.18
Moments:									
mean consumption	0.6833	0.6834	0.01	0.6834	0.01	0.6833	0.00	0.6834	0.01
mean hours	0.9385	0.9386	0.01	0.9386	0.01	0.9384	-0.01	0.9384	-0.01
mean price disp. (T)	1.0009	1.0007	-0.01	1.0007	-0.02	1.0008	-0.01	1.0005	-0.03
mean price disp. (N)	1.0005	1.0004	-0.01	1.0004	-0.01	1.0006	0.01	1.0002	-0.03
std. dev. consumption	0.0063	0.0081	28.58	0.0064	2.82	0.0119	89.86	0.0165	164.22
std. dev. hours	0.0169	0.0147	-13.00	0.0176	3.95	0.0086	-49.03	0.0059	-65.39
std. dev. CPI inflation	0.0035	0.0033	-6.09	0.0033	-7.12	0.0040	13.53	0.0028	-21.66
std. dev. inflation diff.	0.0015	0.0014	-5.52	0.0013	-12.20	0.0014	-7.87	0.0013	-16.77
std. dev. cons. tax	-	0.0085	-	-	-	0.0153	-	0.0272	-
std. dev. labour tax	-	-	-	0.0066	-	0.0141	-	0.0038	-
std. dev. lump-sum tax	0.0155	0.0149	-3.87	0.0185	19.35	-	-	-	-

Table 3.1: Welfare costs $\times 10^{-3}$, theoretical moments, and percentage gains and differences under the welfare-maximising tax rule (responsive) relative to constant taxes (baseline)

This partial adjustment of the price level leads to price dispersion across different varieties of goods produced by the continuum of intermediate-goods producers. The larger the response of inflation, the wider is the underlying dispersion across prices. Price dispersion causes an inefficient allocation of resources as retailers use different quantities of the available varieties to produce the final good. The inefficiency in the production process of the final good ultimately results in a lower mean of consumption in the ergodic distribution of the model.

Considering rules (1) and (2), the responsive consumption tax performs better at its optimum than the labour income tax. In both cases, the bulk of the welfare gain originates in the mean component of consumption, i.e. by actively compressing inflation and inflation differentials, the fiscal authority compresses the level of price dispersion and thus increases mean consumption in the ergodic distribution of the model.

Both hybrid rules, which abstract from lump-sum taxes, outperform rules (1) and (2). Welfare costs are reduced to the largest extent under Rule (3), where labour income taxes balance the budget. Under both hybrid rules only the volatility component of consumption suffers, whereas the remaining components of the welfare costs improve.

The picture presented by Table 3.1 suggests that the hybrid rules can outperform the rules where the budget is balanced by lump-sum taxes. This result might, however, hinge on the type of shock causing the inflation differential. The following paragraphs repeat the previous analysis for the complete shock structure specified in the calibration, as well as for technology or government spending shocks only, to assess the robustness of the previous findings. The mechanism for each rule is discussed using impulse response functions for shocks to domestic government spending and productivity in the non-traded sector that cause an inflation differential of the home economy of 0.1 percentage points on impact.

Spillovers to the other sector's technology are disabled for the impulse response functions. As the rules work similarly under both types of technology shocks, only the impulse response function to non-traded technology will be discussed.

3.4.1 Rule (1) by shock specification

Table 3.2 displays the decomposition of the gains in welfare from the consumption tax rule when lump-sum taxes balance the budget conditional on the shock specification, i.e. under the complete shock structure as well as under technology or government spending shocks only. Rule (1) performs similarly well under demand and supply disturbances, as in both cases the highest gain stems from the mean component of consumption, while mean hours and consumption volatility effects lower the benefits from the consumption tax rule.

	Complete shock structure			Technology shocks only			Government spending shocks only		
	baseline	responsive	$\Delta\%$	baseline	responsive	$\Delta\%$	baseline	responsive	$\Delta\%$
Welfare loss of fluctuations	-1.0378	-0.9945	4.17	-0.5555	-0.5353	3.63	-0.4820	-0.4588	4.79
Decomposition:									
v_{meanC}:	-0.7694	-0.6787	8.74	-0.4834	-0.4290	9.80	-0.2860	-0.2497	7.53
v_{meanL}:	-0.0825	-0.1375	-5.30	-0.0293	-0.0549	-4.60	-0.0532	-0.0826	-6.11
$v_{volatilityC}$:	-0.0422	-0.0696	-2.63	-0.0326	-0.0473	-2.63	-0.0094	-0.0221	-2.64
$v_{volatilityL}$:	-0.1437	-0.1087	3.36	-0.0101	-0.0042	1.06	-0.1334	-0.1044	6.01
Moments:									
mean consumption	0.6833	0.6834	0.01	0.6835	0.6835	0.01	0.6836	0.6837	0.01
mean hours	0.9385	0.9386	0.01	0.9385	0.9385	0.00	0.9385	0.9385	0.00
mean price disp. (T)	1.0009	1.0007	-0.01	1.0006	1.0005	-0.01	1.0003	1.0002	-0.00
mean price disp. (N)	1.0005	1.0004	-0.01	1.0003	1.0002	-0.01	1.0003	1.0002	-0.01
std. dev. consumption	0.0063	0.0081	28.58	0.0055	0.0066	20.42	0.0030	0.0045	53.47
std. dev. hours	0.0169	0.0147	-13.00	0.0045	0.0029	-35.39	0.0163	0.0145	-11.53
std. dev. CPI inflation	0.0035	0.0033	-6.09	0.0026	0.0024	-6.72	0.0024	0.0023	-5.37
std. dev. inflation diff.	0.0015	0.0014	-5.52	0.0011	0.0011	-5.47	0.0010	0.0009	-5.57
std. dev. cons. tax	-	0.0085	-	-	0.0064	-	-	0.0056	-
std. dev. labour tax	-	-	-	-	-	-	-	-	-
std. dev. lump-sum tax	0.0155	0.0149	-3.87	0.0027	0.0055	103.07	0.0152	0.0139	-8.55

Table 3.2: Welfare costs $\times 10^{-3}$, theoretical moments, and percentage gains and differences under Rule (1) at $\zeta^* = 6$ (responsive) relative to constant distortionary taxes (baseline) by shock specification

The benefits of raising the consumption tax in response to a positive domestic inflation differential can be explained using impulse response functions. Figure 3.2 displays the impulse response functions of key variables of the model for a shock to technology in the non-traded sector for the baseline scenario as well as under the responsive consumption tax rule ($\zeta^* = 6$). The increase in productivity triggers a fall in marginal costs of the firms producing non-traded goods so that these firms seek to lower prices. Non-traded goods become relatively cheaper than traded goods, so the internal terms of trade fall. Firms in the non-traded sector lower their demand for labour, causing a fall in the domestic nominal wage and thus the marginal costs of the intermediate firms in the traded sector too. They can hence lower their prices as well, which improves the external terms of trade. Consumer price inflation falls below the union-average and H faces a negative inflation differential.

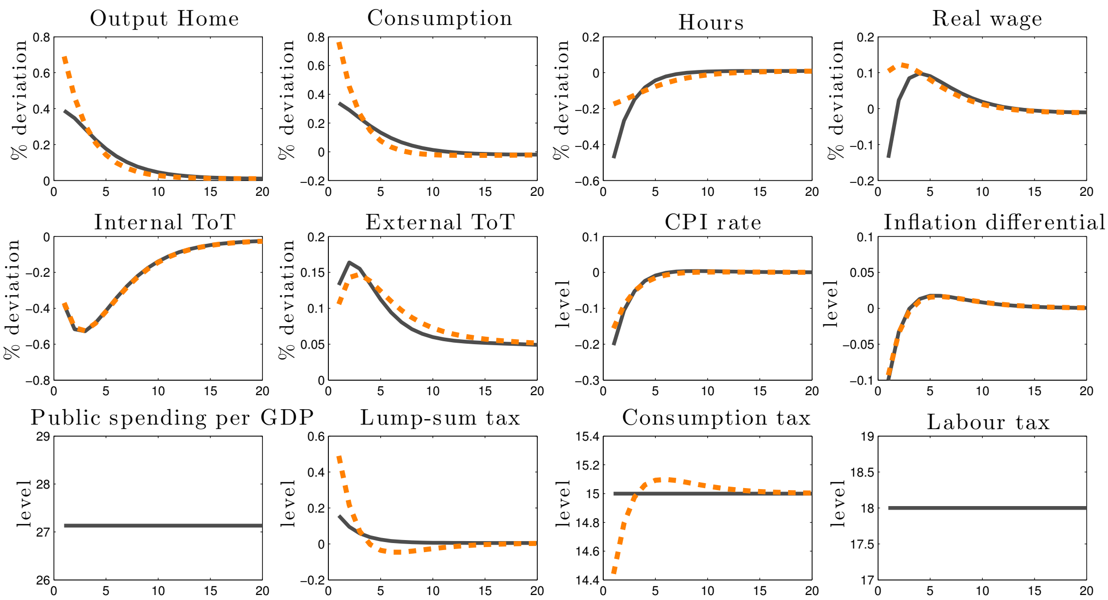


Figure 3.2: Impulse response functions after a shock to Z_N of one standard deviation under Rule (1)
Baseline = solid line, responsive Rule (1) = orange dotted line

Under Rule (1), the consumption tax is lowered in response to the negative inflation differential, so that consumption increases by more relative to the baseline scenario due to lower prices and taxes on consumption goods. The increase in domestic demand is met by a stronger increase in production, which drives up marginal costs for all firms causing them to lower prices by less compared to the baseline scenario. As a consequence, the response of CPI inflation and the inflation differential is slightly dampened. The impulse response functions confirm the observations from Table 3.2 that Rule (1) is able to dampen the responses of hours, CPI inflation, and the domestic inflation differential while raising the volatility of consumption. The compression of inflation lowers mean price dispersion, which explains the large gain arising from the mean component of consumption.

A government spending shock increases the demand for non-traded goods such that firms in this sector increase their production, as displayed in Figure 3.3. Marginal costs rise and firms in the non-traded sector seek to raise their prices. The internal terms of trade increase. Higher non-traded output implies a higher demand for labour and thus higher economy-wide wages, driving up marginal costs for firms and thus also prices in the traded sector. Relative to foreign-produced traded goods, home-produced traded goods become more expensive, as evidenced by the deterioration of the external terms of trade. Overall, inflation increases relative to the union and the economy faces a positive inflation differential.

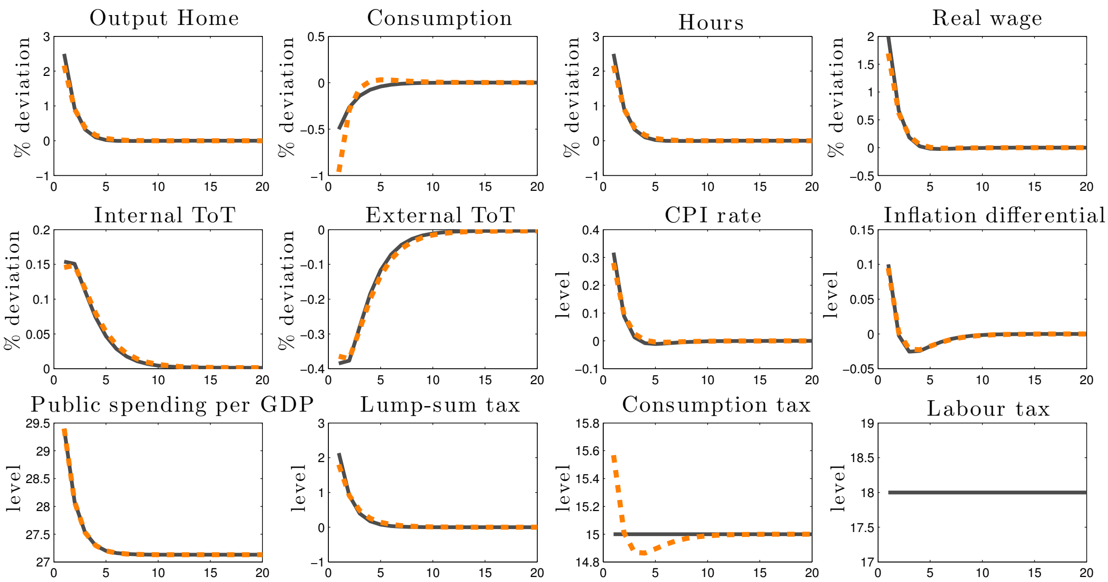


Figure 3.3: Impulse response functions after a shock to G/Y of one standard deviation under Rule (1)
Baseline = solid line, responsive Rule (1) = orange dotted line

Under Rule (1), consumption taxes increase, leading to a more pronounced fall in domestic consumption compared to the baseline scenario due to higher prices as well as consumption taxes. As a result, firms in the non-traded sector raise their production by less after a government spending shock. Marginal costs, the demand for labour, and the nominal wage increase by less. The policy dampens the response of CPI inflation and thus the inflation differential.

Again, the impulse response functions confirm the picture presented by Table 3.2. Under the government spending shock, the responsive consumption tax slightly compresses inflation responses as well as the response of hours but raises the volatility of consumption. The compression of inflation gives smaller room for price dispersion, explaining the gain arising in the mean consumption component.

3.4.2 Rule (2) by shock specification

In contrast to Rule (1), Rule (2) does not perform equally well under supply and demand disturbances. Table 3.3 shows that the responsive labour income tax rule raises welfare costs for the given sensitivity ($\zeta^* = -5$) when only government spending shocks are present in the model. Under technology shocks only, the benefits from Rule (2) arise from mean effects in both consumption and hours, while volatility effects slightly dampen the benefits. Under government spending shocks only, a gain still arises in the mean component of consumption but is outweighed by a large loss in the mean component of hours as well as in both volatility components.

Figure 3.4 illustrates the mechanism of the fiscal rule for labour income taxes when responding to an inflation differential caused by a shock to non-traded sector technology relative to the baseline discussed earlier. In response to a negative inflation differential, the labour income tax is raised at the given

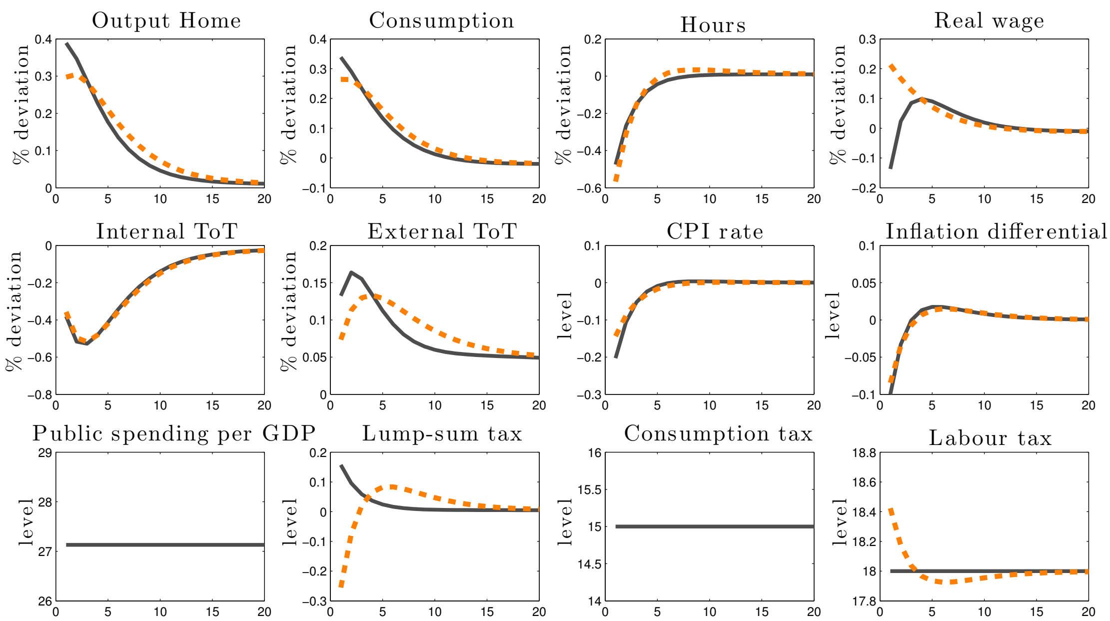


Figure 3.4: Impulse response functions after a shock to Z_N of one standard deviation under Rule (2)
Baseline = solid line, responsive Rule (2) = orange dotted line

sensitivity. The nominal wage increases to satisfy the labour supply decision of the household, raising marginal costs in both sectors. This leads firms in both sectors to lower their prices by less compared to the baseline scenario.

	Complete shock structure			Technology shocks only			Government spending shocks only		
	baseline	responsive	Δ%	baseline	responsive	Δ%	baseline	responsive	Δ%
Welfare loss of fluctuations	-1.0378	-1.0188	1.83	-0.5555	-0.5115	7.93	-0.4820	-0.5070	-5.20
Decomposition:									
v_{meanC}:	-0.7694	-0.6845	8.17	-0.4834	-0.4259	10.36	-0.2860	-0.2587	5.66
v_{meanL}:	-0.0825	-0.1344	-5.00	-0.0293	-0.0348	-0.99	-0.0532	-0.0996	-9.63
$v_{volatilityC}$:	-0.0422	-0.0446	-0.23	-0.0326	-0.0346	-0.35	-0.0094	-0.0098	-0.09
$v_{volatilityL}$:	-0.1437	-0.1552	-1.11	-0.0101	-0.0162	-1.09	-0.1334	-0.1389	-1.15
Moments:									
mean consumption	0.6833	0.6834	0.01	0.6835	0.6835	0.01	0.6836	0.6837	0.00
mean hours	0.9385	0.9386	0.01	0.9385	0.9385	0.00	0.9385	0.9385	0.01
mean price disp. (T)	1.0009	1.0007	-0.02	1.0006	1.0005	-0.01	1.0003	1.0002	-0.01
mean price disp. (N)	1.0005	1.0004	-0.01	1.0003	1.0002	-0.01	1.0003	1.0002	-0.01
std. dev. consumption	0.0063	0.0064	2.82	0.0055	0.0057	3.00	0.0030	0.0030	2.22
std. dev. hours	0.0169	0.0176	3.95	0.0045	0.0057	26.39	0.0163	0.0167	2.05
std. dev. CPI inflation	0.0035	0.0033	-7.12	0.0026	0.0024	-7.68	0.0024	0.0022	-6.45
std. dev. inflation diff.	0.0015	0.0013	-12.20	0.0011	0.0010	-12.22	0.0010	0.0009	-12.17
std. dev. cons. tax	-	-	-	-	-	-	-	-	-
std. dev. labour tax	-	0.0066	-	-	0.0050	-	-	0.0044	-
std. dev. lump-sum tax	0.0155	0.0185	19.35	0.0027	0.0043	59.26	0.0152	0.0180	18.42

Table 3.3: Welfare costs $\times 10^{-3}$, theoretical moments, and percentage gains and differences under Rule (2) at $\zeta^* = -5$ (responsive) relative to constant distortionary taxes (baseline) by shock specification

The smaller drop in prices dampens the increase in domestic demand by domestic households so that firms' output increases by less under the responsive fiscal rule compared to the baseline scenario. As reported in Table 3.3, the volatility of CPI inflation and the inflation differential is lowered leading to lower price dispersion in expectations. This explains the large gain that arises in the mean component of consumption.

Figure 3.5 repeats the analysis for a government spending shock and shows that firms in the non-traded sector still increase their production. However, lower labour income taxes lead to a smaller increase in the nominal wage that is necessary to fulfil the labour supply decision of the household.

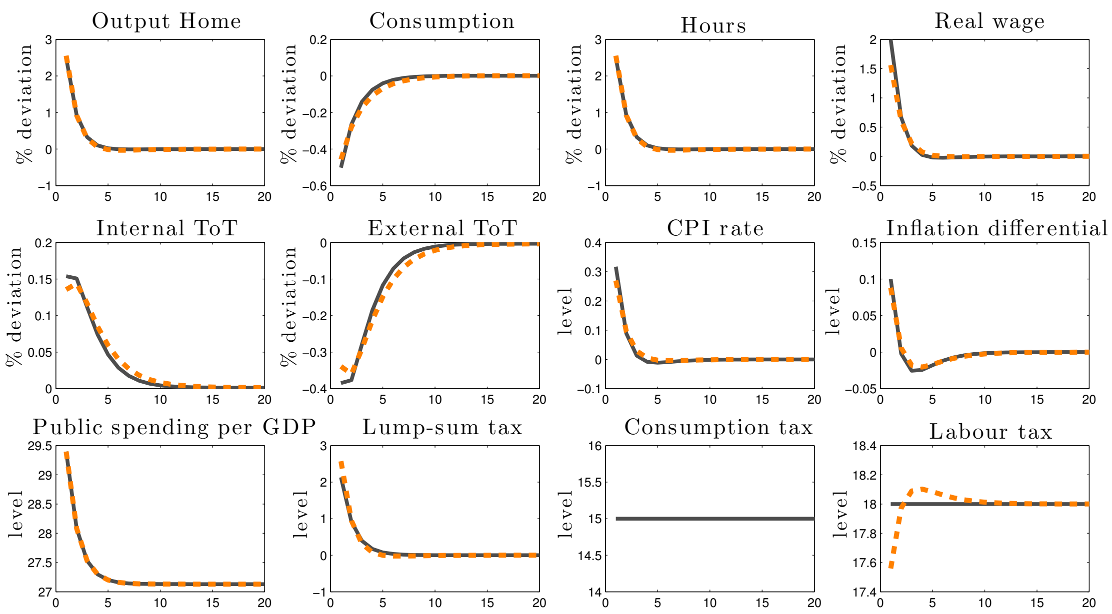


Figure 3.5: Impulse response functions after a shock to G/Y of one standard deviation under Rule (2)
Baseline = solid line, responsive Rule (2) = orange dotted line

As a consequence, marginal costs in both sectors increase by less, causing a smaller response of inflation under the responsive fiscal rule as shown also by the lower volatility of the inflation variables in Table 3.3.

3.4.3 Rule (3) by shock specification

The previous paragraphs established the benefits of raising (lowering) consumption (labour income) taxes in response to a positive domestic inflation differential and to what extent these benefits are dependent on the shock structure. It remains to be clarified to what extent the hybrid rules are able to outperform the previously discussed rules that rely on lump-sum financing of the fiscal budget. Under Rule (3) the fiscal authority raises the consumption tax while labour income taxes balance the budget when domestic inflation exceeds the union-wide aggregate. Table 3.4 shows that Rule (3) is beneficial under either shock structure at the given sensitivity.

Under technology shocks only, the gain in welfare stems largely from the mean component of consumption due to lower price dispersion, while the volatility of consumption increases. Yet despite a reduction of the welfare loss under government spending shocks, Rule (3) destabilises inflation and the inflation differential and raises price dispersion. In order to understand these findings, Figure 3.6 displays the mechanism of Rule (3) following a technology shock in the non-traded sector.

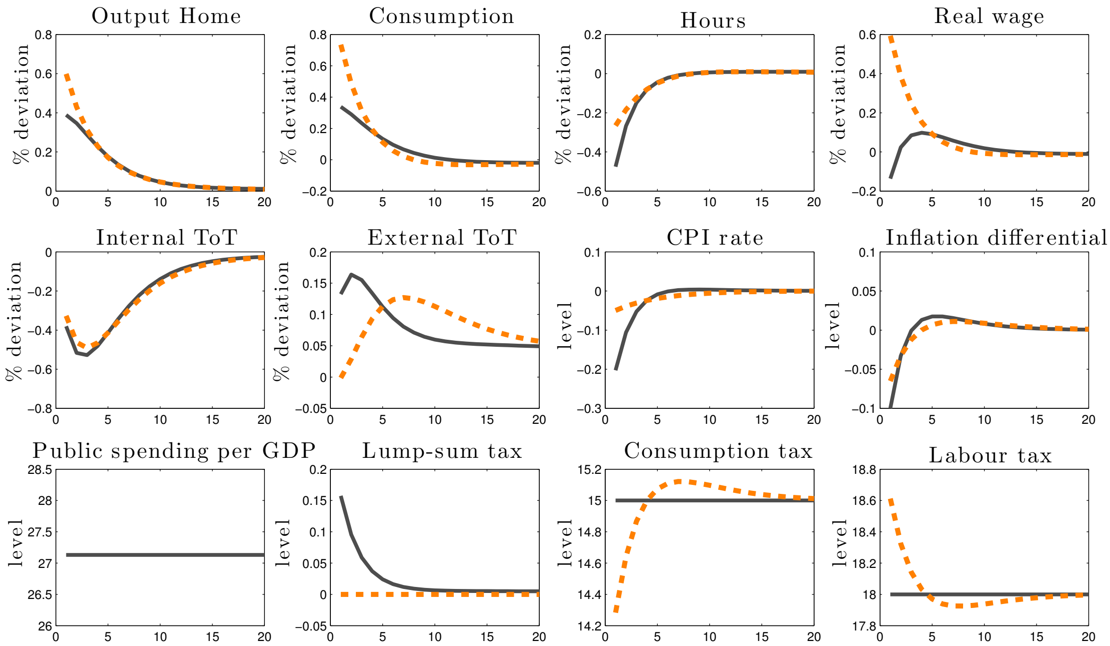


Figure 3.6: Impulse response functions after a shock to Z_N of one standard deviation under Rule (3)
Baseline = solid line, responsive Rule (3) = orange dotted line

As under Rule (1), lowering of the consumption tax increases domestic demand, raising production and marginal costs in both sectors so that domestic firms lower their prices by less. At the same time, the labour income tax increases to finance the proportional increase in government spending, letting the nominal wage increase, thereby driving up marginal costs even further. The response of domestic inflation to the technology shock is dampened to a large extent because Rule (3) combines the benefits of rules (1) and (2). Consumption taxes fall while labour income taxes increase in response to the domestic inflation differential, making the hybrid rule highly effective in light of technology shocks.

	Complete shock structure			Technology shocks only			Government spending shocks only		
	baseline	responsive	Δ%	baseline	responsive	Δ%	baseline	responsive	Δ%
Welfare loss of fluctuations	-1.0378	-0.9276	10.62	-0.5555	-0.4656	16.18	-0.4820	-0.4615	4.24
Decomposition:									
v_{meanC}:	-0.7694	-0.7435	2.50	-0.4834	-0.4104	13.14	-0.2860	-0.3330	-9.77
v_{meanL}:	-0.0825	0.0047	8.40	-0.0293	-0.0043	4.51	-0.0532	0.0090	12.89
$v_{volatilityC}$:	-0.0422	-0.1515	-10.52	-0.0326	-0.0440	-2.05	-0.0094	-0.1071	-20.27
$v_{volatilityL}$:	-0.1437	-0.0373	10.25	-0.0101	-0.0069	0.59	-0.1334	-0.0303	21.39
Moments:									
mean consumption	0.6833	0.6833	0.00	0.6835	0.6836	0.01	0.6836	0.6836	0.00
mean hours	0.9385	0.9384	-0.01	0.9385	0.9384	-0.00	0.9385	0.9384	-0.01
mean price disp. (T)	1.0009	1.0008	-0.01	1.0006	1.0003	-0.03	1.0003	1.0004	0.02
mean price disp. (N)	1.0005	1.0006	0.01	1.0003	1.0002	-0.01	1.0003	1.0004	0.02
std. dev. consumption	0.0063	0.0119	89.86	0.0055	0.0064	16.24	0.0030	0.0100	237.75
std. dev. hours	0.0169	0.0086	-49.03	0.0045	0.0037	-17.63	0.0163	0.0078	-52.34
std. dev. CPI inflation	0.0035	0.0040	13.53	0.0026	0.0024	-6.60	0.0024	0.0032	32.82
std. dev. inflation diff.	0.0015	0.0014	-7.87	0.0011	0.0008	-29.95	0.0010	0.0011	14.74
std. dev. cons. tax	-	0.0153	-	-	0.0087	-	-	0.0125	-
std. dev. labour tax	-	0.0141	-	-	0.0074	-	-	0.0119	-
std. dev. lump-sum tax	0.0155	-	-	0.0027	-	-	0.0152	-	-

Table 3.4: Welfare costs $\times 10^{-3}$, theoretical moments, and percentage gains and differences under Rule (3) at $\zeta^* = 11$ (responsive) relative to constant distortionary taxes (baseline) by shock specification

Rule (3) works differently, however, for government spending shocks as displayed in Figure 3.7. It prescribes an increase in consumption taxes as well as an increase in labour income taxes to finance public spending. Private demand is drastically lowered and the nominal wage increases to make up for the tax

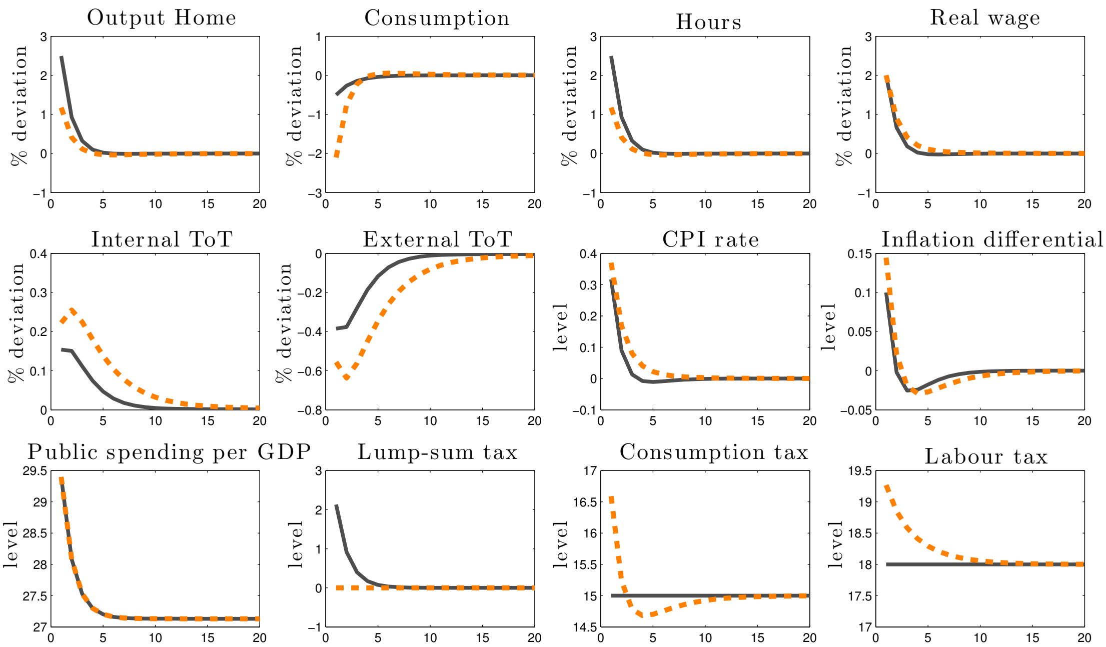


Figure 3.7: Impulse response functions after a shock to G/Y of one standard deviation under Rule (3)
Baseline = solid line, responsive Rule (3) = orange dotted line

hikes, raising marginal costs despite lower production. At the given sensitivity, CPI inflation as well as the inflation differential react more strongly to the domestic government spending shock, which explains the higher volatility of these two variables in Table 3.4. In contrast to the case of technology shocks, the compression of inflation under government spending shocks fails due to the comovement of the two tax instruments.

3.4.4 Rule (4) by shock specification

After establishing that the hybrid rule, Rule (3), can outperfom the rules relying on lump-sum taxes when the tax instruments move in opposite directions, one must now ask how Rule (4) compares to Rule (3). Table 3.5 shows that, similarly to Rule (3), Rule (4) lowers welfare costs of business cycle fluctuations under both demand and supply disturbances for the given sensitivity. In contrast to Rule (3), however, Rule (4) successfully compresses inflation and raises mean consumption under either shock structure.

	Complete shock structure			Technology shocks only			Government spending shocks only		
	baseline	responsive	Δ%	baseline	responsive	Δ%	baseline	responsive	Δ%
Welfare loss of fluctuations	-1.0378	-0.9652	6.99	-0.5555	-0.5312	4.37	-0.4820	-0.4338	9.99
Decomposition:									
v_{meanC}:	-0.7694	-0.6451	11.98	-0.4834	-0.4790	0.80	-0.2860	-0.1661	24.87
v_{meanL}:	-0.0825	-0.0100	6.99	-0.0293	-0.0141	2.74	-0.0532	0.0042	11.90
$v_{volatilityC}$:	-0.0422	-0.2930	-24.16	-0.0326	-0.0280	0.84	-0.0094	-0.2649	-53.00
$v_{volatilityL}$:	-0.1437	-0.0172	12.18	-0.0101	-0.0101	0.00	-0.1334	-0.0071	26.21
Moments:									
mean consumption	0.6833	0.6834	0.01	0.6835	0.6835	0.00	0.6836	0.6837	0.01
mean hours	0.9385	0.9384	-0.01	0.9385	0.9385	-0.00	0.9385	0.9384	-0.01
mean price disp. (T)	1.0009	1.0005	-0.03	1.0006	1.0005	-0.01	1.0003	1.0000	-0.02
mean price disp. (N)	1.0005	1.0002	-0.03	1.0003	1.0002	-0.01	1.0003	1.0000	-0.02
std. dev. consumption	0.0063	0.0165	164.22	0.0055	0.0051	-7.41	0.0030	0.0157	431.17
std. dev. hours	0.0169	0.0059	-65.39	0.0045	0.0045	-0.07	0.0163	0.0038	-76.99
std. dev. CPI inflation	0.0035	0.0028	-21.66	0.0026	0.0024	-4.96	0.0024	0.0013	-46.71
std. dev. inflation diff.	0.0015	0.0013	-16.77	0.0011	0.0010	-9.35	0.0010	0.0007	-27.56
std. dev. cons. tax	-	0.0272	-	-	0.0046	-	-	0.0268	-
std. dev. labour tax	-	0.0038	-	-	0.0031	-	-	0.0022	-
std. dev. lump-sum tax	0.0155	-	-	0.0027	-	-	0.0152	-	-

Table 3.5: Welfare costs $\times 10^{-3}$, theoretical moments, and percentage gains and differences under Rule (4) at $\zeta^* = -3$ (responsive) relative to constant distortionary taxes (baseline) by shock specification

Figure 3.8 illustrates the mechanism of Rule (4) for a shock to technology in the non-traded sector. As under Rule (2), labour income taxes increase, leading to increases in the nominal wage and thus marginal costs for domestic firms which accordingly lower their prices by less compared to the baseline scenario.

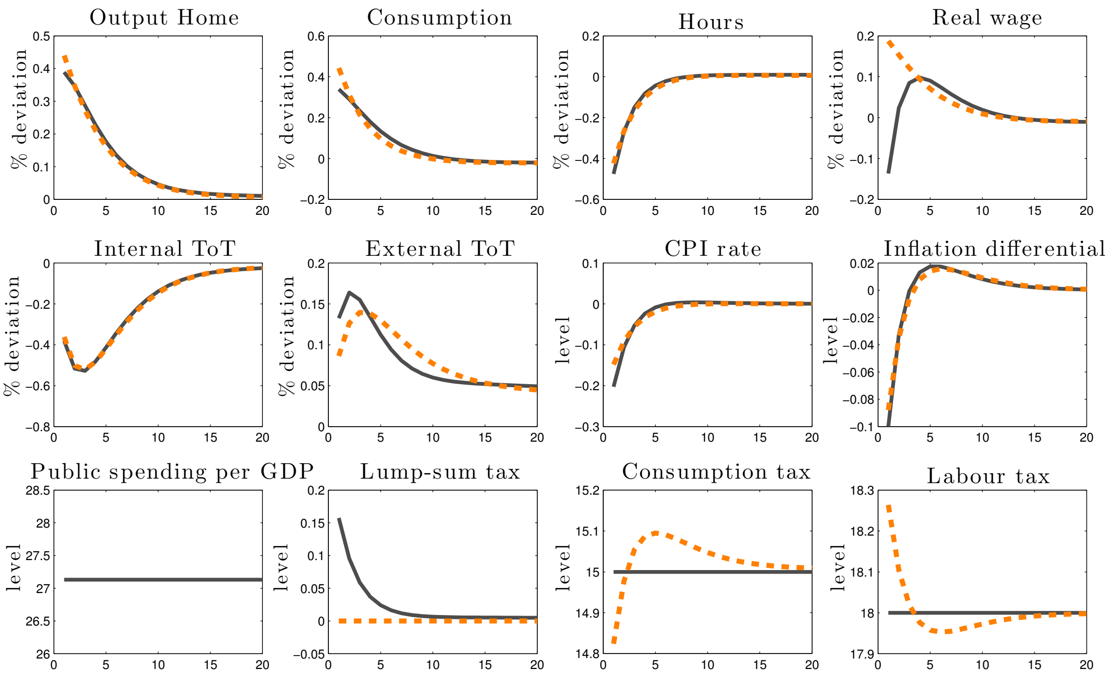


Figure 3.8: Impulse response functions after a shock to Z_N of one standard deviation under Rule (4)
Baseline = solid line, responsive Rule (4) = orange dotted line

Public spending increases proportionally to output at lower prices. Given a higher labour tax income, consumption taxes decrease to balance the fiscal budget. As in the case of Rule (3), the large gains in welfare arise because the two tax instruments move in opposite directions and thus combine the benefits of rules (1) and (2) in compressing inflation.

Table 3.5 suggests that, in contrast to Rule (3), Rule (4) compresses inflation under government spending shocks only. Figure 3.9 shows that labour income taxes fall in response to lower prices, allowing for lower nominal wages and marginal costs so that firms raise their prices by less. Simultaneously, the increase in public spending is financed by higher consumption taxes which lower private demand, thereby further decreasing marginal costs due to decreased production. The result is a largely muted response in domestic inflation and a dampened inflation differential as suggested by Table 3.5. Overall, the large reduction in welfare costs of business cycle fluctuations under Rule (4) under government spending shocks can, as under technology shocks, be explained by the opposed movement of the two tax instruments.

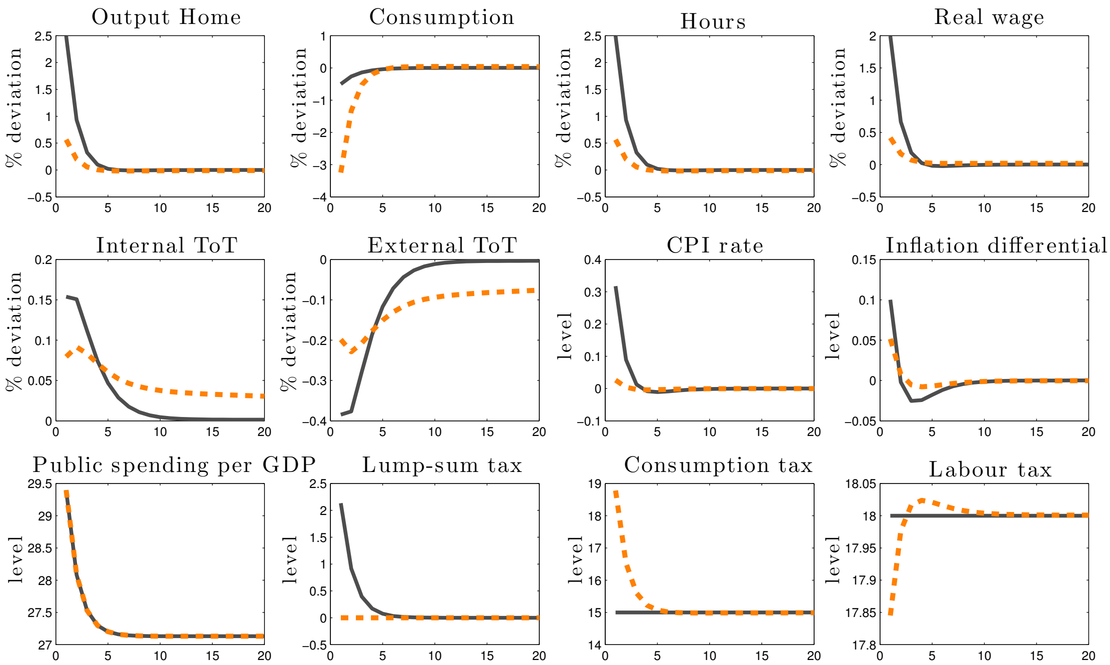


Figure 3.9: Impulse response functions after a shock to G/Y of one standard deviation under Rule (4)
Baseline = solid line, responsive Rule (4) = orange dotted line

Comparing the hybrid rules (3) and (4) with each other, one can make the following observations: despite a larger reduction in welfare costs through Rule (3) both under the complete shock structure and under technology shocks only, Rule (4) is able to compress inflation differentials and raise mean consumption under either shock specification. Rule (3) works along different lines under government spending shocks and actually raises inflation volatility and price dispersion. Under Rule (4) all welfare cost components see an increase except for the volatility of consumption, whereas the mechanism of Rule (3) is dependent on the shock specification. In this respect, Rule (4) delivers a more robust stabilisation mechanism.

3.5 Conclusion

This paper investigates whether a national fiscal authority should strategically react to the domestic inflation differential with an available tax instrument. In a two-country DSGE model with traded and non-traded goods, the analysis considers four fiscal rules: responsive consumption and labour income taxes when the governmental budget is balanced by lump-sum taxes, rules (1) and (2), or by the remaining distortionary tax, rules (3) and (4). It finds a large scope for fiscal intervention. The welfare analysis shows that under demand as well as supply disturbances, all four rules reduce the welfare costs of business cycle fluctuations relative to the benchmark in which distortionary taxes are held constant. Under the full stochastic setup, both hybrid rules for which lump-sum taxes are absent outperform the rules relying on lump-sum financing of government spending.

A robustness analysis discusses the dependence of the findings on the specified shock structure. It finds that, except for the labour income tax rule under government spending shocks only, all rules are beneficial under either type of disturbance, i.e. demand or supply shocks. Comparing the performance of the two hybrid rules shows that letting labour income taxes respond to the domestic inflation differential while consumption taxes balance the budget delivers the most robust stabilisation mechanism. This is because under Rule (4), under both technology as well as government spending shocks, the two tax instruments move in opposite directions. This combines the benefits of the two rules relying on lump-sum financing so that inflation and inflation differentials are largely compressed and mean consumption in the ergodic distribution is raised.

BIBLIOGRAPHY

Abbritti, M. & Mueller, A. I. (2013). Asymmetric labor market institutions in the EMU and the volatility of inflation and unemployment differentials. *Journal of Money, Credit and Banking*, 45(6), 1165–1186.

Altissimo, F., Benigno, P., & Palenzuela, D. (2011). Inflation Differentials in a Currency Area: Facts, Explanations and Policy. *Open Economies Review*, 22(2), 189–233.

An, S. & Schorfheide, F. (2007). Bayesian Analysis of DSGE Models. *Econometric Reviews*, 26(2-4), 113–172.

Andrés, J., Ortega, E., & Vallés, J. (2008). Competition and inflation differentials in EMU. *Journal of Economic Dynamics and Control*, 32(3), 848–874.

Angeloni, I. & Ehrmann, M. (2007). Euro area inflation differentials. *The BE Journal of Macroeconomics*, 7(1).

Balassa, B. (1964). The purchasing-power parity doctrine: A reappraisal. *The Journal of Political Economy*, 72(6), 584–596.

Beetsma, R. M. & Jensen, H. (2004). Mark-up fluctuations and fiscal policy stabilization in a monetary union. *Journal of Macroeconomics*, 26(2), 357–376.

Beetsma, R. M. & Jensen, H. (2005). Monetary and fiscal policy interactions in a micro-founded model of a monetary union. *Journal of international Economics*, 67(2), 320–352.

Bergin, P. R. (2000). Fiscal solvency and price level determination in a monetary union. *Journal of Monetary Economics*, 45(1), 37–53.

Bergstrand, J. H. (1991). Structural determinants of real exchange rates and national price levels: Some empirical evidence. *The American Economic Review*, 81(1), 325–334.

Berka, M., Devereux, M. B., & Engel, C. (2018). Real exchange rates and sectoral productivity in the eurozone. *American Economic Review*, 108(6), 1543–1581.

Beyer, R. C. & Smets, F. (2015). Labour market adjustments and migration in Europe and the United States: How different? *Economic policy*, 30(84), 643–682.

Blanchard, O. J. & Kahn, C. M. (1980). The Solution of Linear Difference Models under Rational Expectations. *Econometrica, Econometric Society*, 48(5), 1305–1311.

Bordo, M. D., Choudhri, E. U., Fazio, G., & MacDonald, R. (2017). The real exchange rate in the long run: Balassa-samuelson effects reconsidered. *Journal of International Money and Finance*, 75, 69–92.

Campolmi, A. & Faia, E. (2011). Labor market institutions and inflation volatility in the euro area. *Journal of Economic Dynamics and Control*, 35(5), 793–812.

Canzoneri, M., Cumby, R., Diba, B., & Mykhaylova, O. (2006). New Keynesian Explanations of Cyclical Movements in Aggregate Inflation and Regional Inflation Differentials. *Open Economies Review*, 17(1), 27–55.

Cardi, O. & Restout, R. (2015). Imperfect mobility of labor across sectors: A reappraisal of the Balassa–Samuelson effect. *Journal of International Economics*, 97(2), 249–265.

Chari, V. V., Kehoe, P. J., & McGrattan, E. R. (2002). Can sticky price models generate volatile and persistent real exchange rates? *The Review of Economic Studies*, 69(3), 533–563.

Choudhri, E. U. & Schembri, L. L. (2010). Productivity, the terms of trade, and the real exchange rate: Balassa–samuelson hypothesis revisited. *Review of International Economics*, 18(5), 924–936.

Corsetti, G., Dedola, L., & Leduc, S. (2008). International risk sharing and the transmission of productivity shocks. *The Review of Economic Studies*, 75(2), 443–473.

Corsetti, G., Martin, P., & Pesenti, P. (2007). Productivity, terms of trade and the 'home market effect'. *Journal of International Economics*, 73(1), 99–127.

De Haan, J. (2010). Inflation differentials in the euro area: a survey. In *The European Central Bank at Ten* (pp. 11–32). Berlin, Heidelberg: Springer.

Druant, M., Fabiani, S., Kezdi, G., Lamo, A., Martins, F., & Sabbatini, R. (2012). Firms' price and wage adjustment in Europe: Survey evidence on nominal stickiness. *Labour Economics*, 19(5), 772–782.

Duarte, M. & Wolman, A. (2002). Regional inflation in a currency union: fiscal policy vs. fundamentals. *European Central Bank Working Paper*, (180).

Duarte, M. & Wolman, A. L. (2008). Fiscal policy and regional inflation in a currency union. *Journal of International Economics*, 74(2), 384–401.

Égert, B. (2007). Real convergence, price level convergence and inflation differentials in Europe. *CESifo Working Paper Series 2127*.

Engler, P., Tervala, J., Ganelli, G., & Voigts, S. (2014). *Fiscal Devaluation in a Monetary Union*. Technical report, Verein für Socialpolitik/German Economic Association.

Evers, M. P. (2012). Federal fiscal transfer rules in monetary unions. *European Economic Review*, 56(3), 507–525.

Evers, M. P. (2015). Fiscal federalism and monetary unions: A quantitative assessment. *Journal of International Economics*, 97(1), 59–75.

Farhi, E., Gopinath, G., & Itskhoki, O. (2014). Fiscal devaluations. *The Review of Economic Studies*, 81(2), 725–760.

Faust, J. & Gupta, A. (2012). *Posterior predictive analysis for evaluating DSGE models*. Technical report, National Bureau of Economic Research.

Ferrero, A. (2009). Fiscal and monetary rules for a currency union. *Journal of International Economics*, 77(1), 1–10.

Gali, J. & Monacelli, T. (2008). Optimal monetary and fiscal policy in a currency union. *Journal of International Economics*, 76(1), 116–132.

Geweke, J. (2007). Bayesian model comparison and validation. *The American Economic Review*, 97(2), 60–64.

Gilchrist, S., Schoenle, R., Sim, J., & Zakrajšek, E. (2017). Inflation dynamics during the financial crisis. *The American Economic Review*, 107(3), 785–823.

Harrod, H. (1933). *International Economics*. London: Cambridge University Press.

Honohan, P. & Lane, P. R. (2003). Divergent inflation rates in EMU. *Economic Policy*, 18(37), 357–394.

Horvath, M. (2000). Sectoral shocks and aggregate fluctuations. *Journal of Monetary Economics*, 45(1), 69–106.

Hristov, N., Hülsewig, O., & Wollmershäuser, T. (2014). Financial frictions and inflation differentials in a monetary union. *The Manchester School*, 82(5), 549–595.

Kirsanova, T., Satchi, M., Vines, D., & Wren-Lewis, S. (2007). Optimal Fiscal Policy Rules in a Monetary Union. *Journal of Money, Credit and Banking*, 39(7), 1759–1784.

Kirsanova, T. & Wren-Lewis, S. (2012). Optimal Fiscal Feedback on Debt in an Economy with Nominal Rigidities. *The Economic Journal*, 122(559), 238–264.

Lan, H. & Meyer-Gohde, A. (2013). Solving DSGE models with a nonlinear moving average. *Journal of Economic Dynamics and Control*, 37(12), 2643–2667.

Leeper, E. M. (1991). Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics*, 27(1), 129–147.

Leeper, E. M., Traum, N., & Walker, T. B. (2017). Clearing up the fiscal multiplier morass. *American Economic Review*, 107(8), 2409–2054.

Leith, C. & Wren-Lewis, S. (2000). Interactions between monetary and fiscal policy rules. *The Economic Journal*, 110(462), 93–108.

Lombardo, G. & Sutherland, A. (2004). Monetary and fiscal interactions in open economies. *Journal of Macroeconomics*, 26(2), 319–347.

López-Salido, D., Restoy, F., & Vallés, J. (2005). *Inflation differentials in EMU: The Spanish case*. Banco de España Working Papers 0514, Banco de España.

Lucas, R. E. (1987). *Models of business cycles*. Basil Blackwell Oxford.

Lucas, R. E. (2003). Macroeconomic priorities. *American Economic Review*, 93(1), 1–14.

Mihaljek, D. & Klau, M. (2008). *Catching-up and inflation in transition economies: the Balassa-Samuelson effect revisited*. BIS Working Papers 270, Bank for International Settlements.

Morsy, H. & Jaumotte, F. (2012). *Determinants of Inflation in the Euro Area: The Role of Labor and Product Market Institutions*. IMF Working Papers 12/37, International Monetary Fund.

Ortega, E. (2003). *Persistent inflation differentials in Europe*. Working Papers 0305, Banco de España; Working Papers Homepage.

Pappa, E. & Vassilatos, V. (2007). The unbearable tightness of being in a monetary union: Fiscal restrictions and regional stability. *European Economic Review*, 51(6), 1492–1513.

Rabanal, P. (2009). Inflation Differentials between Spain and the EMU: A DSGE Perspective. *Journal of Money, Credit and Banking*, 41(6), 1141–1166.

Ratto, M. & Iskrev, N. (2011). Identification analysis of DSGE models with DYNARE. *MONFISPOL*, 225149, 26.

Rogers, J. H. (2007). Monetary union, price level convergence, and inflation: How close is Europe to the USA? *Journal of Monetary Economics*, 54(3), 785–796.

Samuelson, P. A. (1964). Theoretical notes on trade problems. *The Review of Economics and Statistics*, 46(2), 145–154.

Schmitt-Grohé, S. & Uribe, M. (2003). Closing small open economy models. *Journal of International Economics*, 61(1), 163–185.

Sims, C. (1997). Fiscal foundations of price stability in open economies. *SSRN Electronic Journal*.

Smets, F. & Wouters, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, 1(5), 1123–1175.

Stockman, A. C. & Tesar, L. L. (1995). Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements. *American Economic Review*, 85(1), 168–185.

Taylor, J. B. (1993). Discretion versus policy rules in practice. In *Carnegie-Rochester conference series on public policy*, volume 39.

Vogel, L., Roeger, W., & Herz, B. (2013). The performance of simple fiscal policy rules in monetary union. *Open Economies Review*, 24(1), 165–196.

von Thadden, L. & Lipinska, A. (2013). *On the (In) effectiveness of Fiscal Devaluations in a Monetary Union*. Technical report, Verein für Socialpolitik/German Economic Association.

Werning, I. & Farhi, E. (2012). *Fiscal unions*. Technical report, National Bureau of Economic Research.

Woodford, M. (1996). *Control of the public debt: A requirement for price stability?* Technical report, National bureau of economic research.

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